

INTEGRATION OF DECISION SYSTEMS WITH
PRODUCTION INFORMATION FOR OPERATIONS MANAGEMENT

BY

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Ramzi S. Khuri

Dedicated to
my mother Maha, my father Suhail,
my brother Nizar, my uncle Zahi,
and my best friend Wisky

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**Abstract of Dissertation Presented to the Graduate School
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by

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Production costs for citrus operations in Florida have been integrated with extension and management recommendations. This new approach permitted the dissemination of valuable production, management, and cost information among citrus growers. It has helped create a dynamic source of information that would ultimately lead to improved production and management decision making.

A citrus production cost information system (COINS) with three components, namely, a cost entry program, a summary and comparison program, and a decision support system for extension and management recommendations, has been designed, developed, and evaluated. The system collects, averages, and summarizes citrus production costs. It provides a means for growers to compare their operations with industry averages.

An herbicide and weed guide gives appropriate management recommendations and associated costs. Citrus growers from several areas in Florida utilized the system and evaluated its operational performance and its qualifications as a decision and management tool. The system's components were found to operate properly, and the system as a whole was qualified to be a useful management tool.

The data entry component successfully collected, organized, and stored production cost information for numerous grove operations. The summary and comparison component successfully averaged production costs for specific areas and types of operations. It allowed for the comparison of individual grove costs with industry averages. The herbicide and weed guide integrated cost information with extension and management recommendations through an expert system. The successful integration of production costs with management recommendations demonstrated the system's success as an effective decision and management tool.

The utilization of a database management environment provided a comprehensive tool for the development of the information system. The techniques and design methods used in development and integration of various components produced a highly dynamic and flexible system.

CHAPTER I INTRODUCTION

Justification

Citrus growers in Florida are continually striving for improved methods of production in order to increase yield and minimize costs. They are challenged by factors such as weather conditions, consumer demand, market prices, and foreign competition. They must overcome these obstacles by using the best production and management practices available.

The cost of producing citrus is partly accrued through the various grove operations performed during each season. Production cost records are maintained by most operations as a means of keeping track of expenditures, and for record keeping and tax purposes. The amount and detail of cost information recorded depends largely on the size of the operation, and on the importance placed on such records by the operation manager. In some instances grove cost records are hand written, lack any detail, and are mainly used for year-end tax purposes. More detailed costs are kept by some growers who use computers to maintain data on a daily basis. In some instances, growers owning small operations delegate the record keeping task to caretaker operations and cooperatives who usually have the means to maintain large amounts of data on computer.

Growers seldom have the opportunity, however, to compare their production costs with industry averages in a way that will help identify problem areas. Database systems currently being used by large operations to help maintain cost information rarely offer any special data analysis or comparison features. Most specialty financial software available for the citrus industry deals strictly with farm financial records. In most cases the software is used for record keeping purposes. In some cases financial analysis of information is performed by the software, and results in an overview of the operation's financial status, but does not deal with operational costs of individual grove practices.

Information sharing among citrus growers would enhance the dissemination of valuable knowledge on production costs and management practices. A large database system, Florida Agricultural Information Retrieval Systems (FAIRS) (Johnson and Beck, 1986), has been developed to provide growers, researchers, and extension specialists valuable information on management and extension practices, as well as technical information on most topics related to citrus. The information in the database is in the form of text and graphic screens, and is updated with current data on a regular basis. Other information sources such as technical publications, extension specialists, and researchers, also provide growers with a consistent source of information. According to Smith et al. (1988) sources of new technology and production methods

include farm magazines, discussion with human expert or neighbor, and extension service.

There is, however, a lack of availability of adequate information associated with production costs for citrus. There is also a need for a means to communicate this information among growers. Knowledge sharing between citrus growers is the key to achieving a dynamic database of information. Using the "dynamic" approach would result in a more specific and more usable database that would result from simply keeping publications related to a specialist's subject matter area on-line (Jones and Hoelscher, 1987). Furthermore, no attempts have been made to integrate citrus production costs with extension and management recommendations. Such an integration would enhance growers' ability to make better management decisions.

There is no reference in the literature to a dynamic agricultural information system where production costs are collected, pooled, summarized, and linked to appropriate extension and management recommendations.

Objectives

The general objective is to provide citrus growers in Florida with a means of improving their production practices through the enhancement of knowledge and management decision making, by providing an economic basis for extension and management recommendations. This is achieved by developing

and integrating a computer based citrus production cost information system with extension and management recommendations. Information in the system develops and expands through the addition of new management and extension information as well as annually contributed production cost information.

The specific objectives are as follows:

- 1) to identify and classify grove operations associated with citrus production in Florida;
- 2) to design and develop a dynamic database system for collecting and storing production cost information for Florida citrus operations;
- 3) to design and develop a system to query the cost database, average and summarize costs, and generate per acre cost and returns reports;
- 4) to provide a means for comparing individual grove costs with industry averages to aid in problem area identification.
- 5) to design and develop a prototype decision support system to integrate cost information with extension and management recommendations.
- 6) to verify the information system's capabilities to enhance the communication of knowledge between citrus growers through the accessibility of citrus production cost information and related management and extension recommendations.

The remainder of this dissertation is organized as five more chapters. The review of literature in Chapter II gives an overview of management information systems and decision support systems. It also deals with expert systems and cost systems as related to agriculture.

Chapter III discusses the design requirements of the system, including preliminary research, hardware, software, and functional requirements.

The design and development of the information system consisting of a database system for handling citrus production costs and a data summary and comparison are discussed in Chapter IV.

Chapter V deals with the design and development aspects of the prototype decision support system for herbicide application. This chapter also describes the means by which production cost information is integrated with management recommendations.

Chapter VI reports the results and procedures of the evaluation and testing of the coins system. The system was evaluated by various citrus growers, researchers, and citrus extension specialists.

Finally, Chapter VII presents conclusions and recommendations for future work in the area of agricultural information systems.

CHAPTER II REVIEW OF LITERATURE

Management Information Systems

Drechsler and Bateson (1986, p. 53) define a management information system as "an information system that provides a manager with information on the activities and pertinent interrelations about the current status of the production/operation system over which he has control". Smith et al. (1985, p. 2) define management information systems as "integrated computer based systems which provide information to support the operational and decision making functions of management". Murphy (1989) claims that in today's terms, MIS (Management Information Systems) are simply databases. This, he says, is an appropriate title since they are storehouses of all information about a specific subject.

Information systems have become an important decision aid and management tool for operation managers. They have become an essential part of many organizations (Smith et al., 1985). Both decision support systems and expert systems should be included as subsystems of an overall management information system concept.

Agricultural Information Systems

Today's businesses design and develop powerful information systems for themselves. The farm community deserves comparable quality power. To achieve this goal, farmers must become involved in the design and development of their systems (Murphy, 1989).

Computer-based systems that are designed specifically for agriculture must meet the farmers' challenge (Stone et al., 1986). Agricultural information systems may include a database representing current knowledge about crop systems, and may have the capability to access historical data records and the ability to analyze data and expand on the analysis presented to a user when requested. An information retrieval system designed for farm use would encompass a collection of resources including record keeping facilities such as accounting information and expert systems (Beck, 1988).

The Jackson County Cooperative Extension Service (CES) office, for example, uses an information management system to collect, store, and retrieve extension information, and provide it to clients in the form most suitable for their needs (Heatley, 1986). The system saves time and effort that would have otherwise been used to manually order and store information, and pass out CES publications. The information management system uses a database management system to retrieve blocks of text.

Agricultural Technology Transfer

Technology transfer from researchers and other information sources to producers remains inadequate. The main objective of agricultural research is to improve the efficiency of farmers by providing them with valuable information which they need to make cost effective production decisions (Smith et al., 1985). The technology of information communication is made possible through management information systems. Murphy (1989) predicts that in the next decade or so, companies will put a lot of effort into 'networks' that link their information sources together. This will ultimately enhance the information communication process.

The process of knowledge transfer from researcher to producer can also be achieved with the construction of interactive computer based decision support systems (Smith et al., 1985). Such systems use knowledge to create valuable information. In order for decision support systems to be an effective communication tool, various components such as simulation, information analysis, and problem solving models must be integrated within a single framework which can be effectively accessed by different user levels. Lal et al. (1987) state that an effective means of transmitting knowledge from technology generator to technology user would be a process that would permit the end user to question and seek clarification on the recommendations given.

Agricultural Cost Systems

The basic purpose of cost systems is to generate cost information. Cost information may be used to satisfy certain managerial requirements. One objective of cost systems is to assist management in controlling costs (Shah, 1981). Management is in constant need of timely and reliable information on costs incurred by various responsibility factors. Such information will provide management with decision making support, and aid in the process of cost reduction. Shah continues to say that a major concern of management is reducing costs while maximizing profits. A cost reduction process requires knowledge of significant cost items, the cost of major activities, the identification of controllable and non-controllable costs, and the effect of cost reduction in each activity on revenues and profits.

In agriculture, growers must know their production costs in order to be competitive and profitable (Tripeppi and Kucher, 1988). Many microcomputer programs have been developed to provide growers with various types of management information. In some cases, analysis of information is provided in order to give management further insight into the financial position of their operations.

Olson et al. (1986) discusses an annual report that summarizes individual farm records for farms in South Eastern Minnesota. The report shows averages as well as high and low ranges. Whole-farm information as well as enterprise costs

and returns are reported. At year end, individual farmers can compare their operation to the information provided in the report to find areas that need management attention and areas which have above average performance. Some computer aided farm business analyses is performed annually using IBM FINANX software by the extension service, and a summary of individual analyses is prepared.

A microcomputer program has been developed to calculate production costs based on various inputs involved in growing crops (Tripepi and Kucher, 1988). The user enters costs for land, buildings, equipment, general overhead expenses, and cultural practices. The program then produces cost summaries for capital requirements, annual fixed costs, variable cost per hour of equipment, estimated costs of production, and final price per plant. Using this information, growers can compare their prices with those of their competitors and can therefore determine crop profitability. The program saves hours of manual collating and adding production costs and eliminates math errors due to human mistakes.

Another computer program, PPCAM was developed to manage plant production data and enable the user to predict production and profits (Power et al., 1989). Using input data, PPCAM generates labor, material, energy, and indirect cost information. The program can also generate, store, and retrieve reports, summaries and graphics of various parameters. PPCAM uses an integrated project-file language

using several spreadsheet templates and databases to create a user friendly environment.

ABC Systems (1989) has created a comprehensive computer program for agricultural record keeping. The program is mainly an accounting software package that handles information for budgets and plans, cash flows, cash forecasts, cost of production, and offers results and balance sheet analysis.

An economics oriented program is discussed by McGilliard and Clay (1986). The microcomputer program for decision analysis (DECAL) was written to provide a relatively easy and flexible method of analyzing investment decisions. For each decision, DECAL produces a one page report showing business measurements of net cash, present, future, period, and annual values, as well as benefit/cost ratios, return on investment, and payback period.

Decision Support Systems

Decision support systems are an emerging area of research. They can combine database management systems and the branch of artificial intelligence known as knowledge representation. (Beck, 1988). According to Barrett and Beerel (1988), conventional computing is concerned with handling information which might subsequently be used in the decision making process. Data processing organizes data and transforms it from one form into another. Here, information is still at a very basic level. Decision support builds on this by

allowing the manager to view data at a level which is convenient to him.

Producers can use decision support systems to analyze and help solve agricultural problems (Smith et al., 1985). A decision support system should be able to provide appropriate information to decision makers in order for them to operate from a wider knowledge base than they do at present. A decision support system discussed by Pruss (1989), utilizes crop production information in the form of raw data. The system collects, organizes, and summarizes information which is later evaluated and interpreted into knowledge used for crop management decisions.

Decision support systems may include expert systems. Expert systems help alleviate some of the difficulties of using decision support systems with a non-expert client. Expert systems can help users select the most important information for certain questions (Love, 1988). Expert system technology can be applied at different points in the decision support system-user interaction process, data collection, identifying the problem, interfacing with the decision support system, guiding the user through decision support system output, assisting the user in "what if" applications of the decision support system, helping the user select pertinent output and decision weights, and analyze output. It is important to ascertain at what point this application should occur.

Expert Systems

Holt (1988) defines an expert system as a computer program that enables a computer to mimic the logic of an expert in diagnosing problems, selecting alternatives, giving recommendations, and managing operational systems. Expert systems are rule based and reason from one rule to the next, gathering information until the system is able to recommend a decision or provide advice (Helms et al., 1987). Expert systems are highly interactive and generally easy to use (Lal et al., 1987). An expert system user can ask the system questions, change assumptions and even ask for the reasoning behind answers given.

The biggest barrier to agricultural productivity is the knowledge gap that lies between researchers and growers. An expert system approach is ultimately an excellent way to remove this obstacle (Rudd et al., 1986). Expert systems may be used to enhance the capabilities of the researchers and others responsible for the technology transfer process (Lal et al., 1987).

Expert systems may be used as tools for summarizing information and knowledge, diagnosing problems, and for identifying specific objects and conditions such as weeds and diseases. Expert systems can also be used as a teaching tool for non-expert users (Holt, 1988).

McKinion and Lemmon (1985) discuss the role of expert system technology in agriculture. They claim that the first

opportunity for using expert system technology in agriculture is with integrated crop management. Expert systems would take the form of integrated crop management decision aids which would encompass such disciplines as irrigation, nutritional problems, fertilization, weed control, cultivation, herbicide application, insect control and insecticide and/or nematicide application.

Expert systems may also be used for economic applications. Expert systems designed to complement farm financial records and planning systems hold considerable promise as decision aids (Love, 1988). Producers can use expert system technology to assist in synthesizing information to decide the financial state and performance of their operations.

Expert System Applications

System development in agricultural and natural resource management applications has mirrored the growth in recent years of the development and use of expert systems in product design, resource management, and logistics (Lambert and Wood, 1988). A survey of agricultural expert systems currently under development or available for use was completed. The six major subject areas surveyed were crop and livestock production, financial analysis, general shells, marketing, natural resource management, and other areas. Most of the applications surveyed are diagnostic in nature. However, a

few are dedicated to advising users on a variety of concerns from irrigation scheduling to grain marketing to enterprise selection. The survey reveals five programs in the area of financial analysis.

A Financial Analysis Review System (FinARS) (Boggess et al., 1989) is written in INSIGHT 2+ (Information Builders, Inc.). The system provides an evaluation of the financial health of a farm business. It is designed to provide an initial assessment of the overall financial health of the business.

In addition to its capabilities as a diagnostic tool for farmers to provide initial interpretation of their farm's financial situation, FinARS can also be used as a tool for teaching financial analysis concepts to students, county agents, lenders, and farmers.

Lambert and Wood's (1988) survey also included four other expert system applications related to economics that are worth mentioning. A Budget Planner written in PASCAL is an enterprise budget generator that includes a full enterprise analysis. A farm financial document analyzer written in LEVEL 5 is designed to assist producers with financial management decisions for Michigan dairy farms. An agricultural financial analysis expert system is available to give information on a farm's current year performance, financial condition, and debt repayment ability. And finally, a farm loan advisor was written to evaluate farm loan applications.

Helms et al. (1987) discuss a farm level expert system that provides advice regarding farm program participation and changes in farm policy variable. The description and application of the Farm Policy Advisor or FPA was demonstrated on a Southern Blacklands hypothetical farm in Texas.

Richardson et al. (1989) describe an application whereby mini-expert systems are called to develop data from user inputs to be used in a database. A main program CARMS (computer assisted records management system) allows users to build data sets needed by CIRMAN (crop insurance risk management analyzer). The expert system CARMS leads the user through a series of steps to develop a large sophisticated database required for a simulation model.

Linker et al. (1990) discuss a herbicide recommendation program that allows the weed managment expert to build a list of recommended herbicides or herbicide mixtures based on weed species and soil type. The program, written in C, allows the user to obtain a herbicide recommendation from a particular weed problem.

Batchelor et al. (1989) describe a prototype expert system developed to aid in soybean insect pest management decision making. Crop status and insect population information are provided by the user. The decision support system, SMARTSOY, runs a crop growth model to determine subsequent damage to the crop. The crop growth model, SOYGROW, predicts growth and development and final yield of

soybean based on daily weather data for specific soils (Jones and Hoelscher, 1987). Once SOYGROW is run, SMARTSOY gives cost effectiveness of insecticide applications as well as rate and type of insecticide are given.

Database Management Systems

Lal et al. (1987) state that the utilization of database management has made a definite contributions to the technology process. Database management typically involves the mechanics of storing and retrieving large amounts of data (Beck et al., 1987). Efficient database design is essential for file organization, indexing, rapid transaction and query processing rates, and allowing multi-user access and sharing of data. Database management also addresses problems such as data security, maintenance of data accuracy and integrity, and creating data storage separate from the application programs which use the data.

Database Design

Proper database design is imperative when creating an efficient data management environment. Brathwaite (1985) discusses some essential reasons behind careful database design including data redundancy, application performance, data security, and ease of programming.

Hierarchical Models. Hierarchical data models are based on tree-like structures made up of nodes and branches, where

the highest node is called the root, and succeeding lower nodes are called children (Brathwaite, 1989). In hierarchical models, trees are constructed using a father-son approach (Chorafas, 1989). Hierarchical models can range from fairly simple such as in the case of one-to-one or one-to-many relationships, to the more complex many-to-many relationships.

Brathwaite (1989) and Chorafas (1989) both discuss some advantages and disadvantages of hierarchical models. A major advantage is the existence of proven database management systems that utilize the hierarchical model. Another advantage is the simplicity and ease of use of hierarchical models which ultimately will facilitate their employment and utilization by data processing users. Other benefits of hierarchical models include their ability to reduce data dependency, and their capability to efficiently represent decision support system data (Hopple, 1988).

Both authors agree that one of the major disadvantages of using hierarchical data models as a basic structure is their lack of flexibility. This presents difficulties during insertion and deletion operations. Due to strict hierarchical ordering insertion and deletion of files or entities may disrupt the tree structure. Also, deletion of the a parent or father node will result in the deletion of the children associated with that node. Accessibility of information is also mentioned as a disadvantage since a child node is accessible only through its parent node.

Relational Models. Relational database models store information in tables of rows and columns (Singh, 1985). The association of rows and columns in a table is the characteristic that gives the relational data model its name (McNichols and Rushinek, 1988). McNichols and Rushinek discuss that one advantage of the relational model is that operations on tables can be defined mathematically, allowing precise and unambiguous data retrieval. Maier (1983) states that another advantages of this type of data storage is its uniformity.

Data Security

An important part of database design is the incorporation of a system to maintain data security. In an information system with multiple users, a method of ensuring that only authorized persons can access certain data is essential. Most systems use a control of access method whereby a user's identity is verified, and according to his priority, the system assigns him access to certain information (Delobel and Adiba, 1985). Any users attempting to enter the system must identify themselves and then authenticate the identification (Brathwaite, 1985).

Harington (1988) states that the first step in on-line database security is to identify the user. However, in single microcomputer operation systems there are generally no individual user accounts or work areas. Therefore, the

computer assumes that everyone who has access to the keyboard is authorized to use the machine. Consequently, security must be handled at a lower level by the database management system itself.

DBASE III Plus (Ashton-Tate, Inc.) has no features specifically designed for data security, but it is possible to impose some measures of safety through an application program. However, even with the use of a password system through the development of an algorithm, there is nothing that will prevent a knowledgeable user from running DBASE III Plus and accessing data by using ordinary program commands.

In many businesses, however, DBASE III Plus users have not been trained to work directly with the database management system environment. The majority are not computer professionals, but people trained in other areas who use computers to help do their jobs. These users work with application programs whereby interaction with the system is made through menu-driven interfaces and system screen forms. In this case, users can be required to supply a password which governs their access to the program.

Integration of Knowledge Systems and Databases

The integration of expert systems with other conventional software would be beneficial (Holsapple et al., 1987). Some expert system environments have a limited ability to import data from external software. This ability does not, however,

replace integration, which provides a comprehensive environment that makes all business computing abilities available for use at any time, individually or in tandem.

Expert systems should be viewed as a supplement rather than a replacement for existing computer technologies like database management systems (Lal et al., 1987). Stone et al. (1986) describe a Farm Level Expert System (FLEX). FLEX is an integrated system made up of expert systems linked through a common global memory and a database of interrelationships. The integration process involves several stages (Harmon and Sawyer, 1989).

Harmon and Sawyer state that first, it is important to determine whether or not a database is necessary. Databases may be used for maintenance purposes whereby they are used to externalize the parts of a decision support system that change frequently. Databases can also be used as tools for information storage, retrieval, searching, and querying. A database management system is often better suited for efficient search of large volumes of structured information than a expert system is. Data sharing with other applications, and other users, as well as security maintenance, are other reasons that necessitate the use of a databases in decision support system.

Second, Harmon and Sawyer say that the role of databases in decision support systems should be evaluated. An expert system can be used in two different ways: as a front end for

a database, asking questions and then initializing database queries, or as a back end for a database, taking the results of the query and analyzing them with rules in order to make recommendations. Jones and Hoelscher (1987) describe a method of integration whereby an expert system provides an initial information sorting process, and then accesses a main database for more detailed information.

When an expert system is used as a front end for a database, the consultation proceeds in the normal way, with the system asking the user questions and using rules to reach a final conclusion. Once the system reaches a conclusion, it takes the extra step by constructing a database query and searching the database for an even more specific recommendation. The database can hold information that will further elaborate on the recommendation. Gallagher (1988) discusses that the processing of data by decision support systems may be very inefficient if they do not have the ability to work with information proficiently. A solution to this problem requires the system to request processing of data by other programs that are specifically designed to accomplish that task. That is, ask the data base management system to search databases and summarize data.

When used as a back end to a database, an expert system takes the database output and uses the information as input. It then makes judgements based on it, and presents specific suggestions to the end user. Back end applications are

usually used to take the raw data drawn from a database query, process it further, and convert it into specific recommendations. This approach is very effective for providing support to individuals who have difficulty interpreting the database query output. Expert systems are used to build on the results of data processing and decision support by assisting the user with the interpretation of data to formulate responses (Barrett and Beerel, 1988).

Summary

The citrus cost information system discussed in this dissertation integrates several of the technologies addressed in this chapter. A database management environment is used in conjunction with an expert system to provide production cost information and extension and management recommendations.

The cost information system is unique in its ability to provide industry averages in a way that is useful as a decision making tool. The expert system provides information on not only extension and management recommendations, but on the costs associated with these recommendations.

CHAPTER III SYSTEM DESIGN CONSIDERATIONS

During the implementation and use of the Florida Agricultural Information Retrieval System (Johnson and Beck, 1986), Florida citrus growers expressed a need for information on production costs associated with citrus. They needed an economic basis for extension and management recommendations. An information system was needed to provide growers with the means to contribute production cost information for their operations, and in return receive summaries of industry averages. The system would not only provide cost summaries, but would also integrate those costs with appropriate extension and management recommendations to provide a comprehensive decision making tool.

Preliminary Research

Existing Information Sources

The first phase in this project was to determine what was already available for the citrus grower in the form of production cost information. It was found that an annual cost survey has been carried out since 1973 by Ron Muraro, a researcher at CREC (Citrus Research and Education Center) in Lake Alfred, Florida (Muraro and Matthews, 1988). Muraro's

surveys are designed to collect custom charge rate information from citrus caretakers in different citrus producing areas of the state. Written surveys are mailed out once a year to participating caretaker operations. When all information is collected, the relevant data is organized and summarized in annual publications. Although other agricultural cost surveys have been carried out in the past in areas such as potato production, and woody nursery businesses, Muraro's citrus cost surveys are the only ones still being carried out on a regular basis.

Existing Agricultural Software

The next step in the preliminary stages of this project was to determine what types of software packages were being written for Florida citrus operations. Several programs were available through the IFAS (Institute of Food and Agricultural Sciences) software distribution office. After reviewing what the IFAS catalog had to offer it was determined that most of the programs were not written specifically for the citrus grower. Some of the programs required the user to have a considerable amount of computer experience, and it was often necessary for the user to have a certain software package or language such as LOTUS 123 or BASIC to run the programs. Based on visits to software exhibits, agricultural trade shows, and discussions with citrus experts, commercial software proved to be mainly designed for payroll and record

keeping purposes and did not offer the grower any decision support capabilities.

Design Requirements

The User Interface

One of the chief design requirements was a user-friendly yet detailed environment for the user to work in. The development of a user-friendly interface is an important part of any system development (Andriole, 1986). Andriole states that the user interface is the single most important part of today's microcomputer systems. Its design must be approached carefully, and should not be left to chance.

Peart (1988) suggests specific guidelines for the design of user friendly programs. Menu selections should be used to obtain necessary words or strings from the user, rather than requiring typing. The user should be given new information and help when needed. Previously entered information should be kept on the screen as long as possible. A user should always have a way reexamine his data and go back and change it. And finally, files should be designed to allow the user to refer back to what he did in his last session.

Lal et al. (1990) discuss an interface program designed to work in conjunction with an expert system. Specially designed screens use pop-up menus with user defined options for data selection. The program acts as an information manager for an integrated decisions support system, FARMSYS.

Once data items are defined, they need not be entered again. This ensures consistency of data and facilitating rule handling, error-checking, logical decisions, and searches during program operation.

The system user was assumed to be a novice computer user. The program had to be easy to use, self explanatory, flexible, and expandable. Paller and Laska (1990) stress the importance of ensuring that a system maintains enough flexibility and responsiveness to meet the real and changing needs of an organization.

System Hardware and Software Requirements

It was felt that the majority of citrus growers in Florida that utilized microcomputers in their operations owned IBM or compatible machines. The system needed to run on the hardware already available in order to avoid additional requirements.

Software specifications required a stand-alone system. As discussed above, a large number of the programs already available through IFAS required additional software to run. This often necessitates costly software packages to be purchased by the user. If such supporting programs were to be distributed with the information system, then the need for expensive licenses would arise.

Functional Requirements

In order for any computer based system to be successful, it must fulfill two requirements. It needs to perform the tasks it was originally designed for, and it must offer the end user enough benefits to justify the time invested in its use. Any system must provide the user with a new or improved method of performing a task by replacing outdated methods or technologies and enhancing productivity. Software systems must also provide information that complements or supplements information already available to the user through conventional means.

A citrus cost information system would require large amounts of data to be contributed by the user. It is often a labor intensive and time consuming task for a grower to contribute production costs for several of his groves by entering detailed information into a computer. In the case of this project, the system needed to provide the user with an incentive to encourage its utilization. This is achieved by providing the user with valuable information in the form of industry averages and management recommendations, and integrating the two in a unique and beneficial manner. The system would also offer the user the chance to compare his operational costs with the industry averages in order to identify possible problem areas.

CHAPTER IV
COINS - CITRUS COST INFORMATION SYSTEM

An Overview of COINS

A Citrus Cost Information System (COINS) was developed to collect, manage, and report costs associated with citrus production in Florida. The program consists of three main sections. The first is a data gathering program for production costs for various areas of the operation. The second section is a summary and comparison program which provides detailed summaries of averaged production costs, and allows the user to compare production costs for one of his groves with industry averages. The third section integrates production cost information with extension and management recommendations. The system for integrating management and cost information (SIMON) is discussed in more detail in Chapter V.

The following section discusses COINS in more detail, including software and computer languages used for development, the overall program structure, and program execution.

DBXL as a Database Management and a Programming Environment

To write the COINS programs, software which combined database management with a comprehensive programming environment was needed. Two relational database packages were considered, DBASE III+, and DBXL (WordTech Systems, Inc.) a similar database program. Both packages offered a database management environment, as well as a programming language with which to develop applications.

DBXL was chosen over DBASE III+ for its increased flexibility and lower cost. DBXL offers an extended language, and an added windowing feature which allows multiple windows to be generated. This feature was found to be helpful in designing menus, pop-up help screens, error message windows, and in improving the overall quality of the user interface. Quicksilver (WordTech Systems, Inc.) was used to compile the database applications to create fast stand-alone programs. This allowed COINS to run independently of dBXL. Thus circulation of the programs would not infringe on any copyright or distribution laws.

Program Development Tools

COINS was developed on a Compaq 386 computer running under an MS-DOS environment. A memory resident editor was used to write the programs. Windowing environments such as Microsoft Windows 386, and Quarterdeck's Desqview 386 were used to load and run all the necessary software

simultaneously. This allowed the programs to be written with the editor, tested in a dBXL environment, compiled with Quicksilver, and tested, with great efficiency.

Program Requirements

The system was designed to run on any IBM-PC, XT, AT and compatibles as well as 386 based machines. Hardware requirements include a minimum of 640 kilobytes of free RAM, a hard disk drive, and a color monitor. The COINS program files occupy approximately one megabyte of disk space. The data files require 60 kilobytes of disk space per grove. An additional 50 kilobytes of free disk space per grove is recommended to accommodate the temporary files during execution of the data summary and comparison program.

Program execution speed depends on the hard disk drive access times, the microprocessor speed of the computer being used, and on the presence or absence of a coprocessor chip. Execution is fairly slow on PC and XT machine, and fastest on 386 computers.

Program Structure

COINS incorporates numerous database files and three main programs, namely a data entry program, a summary and comparison program, and a decision support system. All programs are accessed through a main menu program written in Turbo PASCAL (Borland). When COINS is started, the main menu

is loaded into memory and remains in memory until the session ends. When execution of a program is complete, control returns to the main menu (Figure 4-1).

Password System

COINS utilizes a password system that serves three purposes. The first is to protect data files against unauthorized access. Grove cost information can only be entered or retrieved when the proper password is used. The second purpose is to insure that a user has entered cost information for at least two groves before he is allowed access to the data summary and comparison program. And finally, passwords along with grove ID numbers are used as a means of identifying groves in the database.

The COINS Database

Database Structure

The first step in developing a database to hold citrus production costs, was to establish a list of grove practices. Such a list was already available in Muraro's surveys. Muraro listed ten major grove practices (cost categories), each with its own list of sub-categories. Using Muraro's list as a basis, a modified set of cost categories and sub-categories was created. Each category had five different types of costs associated with it; overall, labor, machinery, management, and material costs. Database files used for cost information

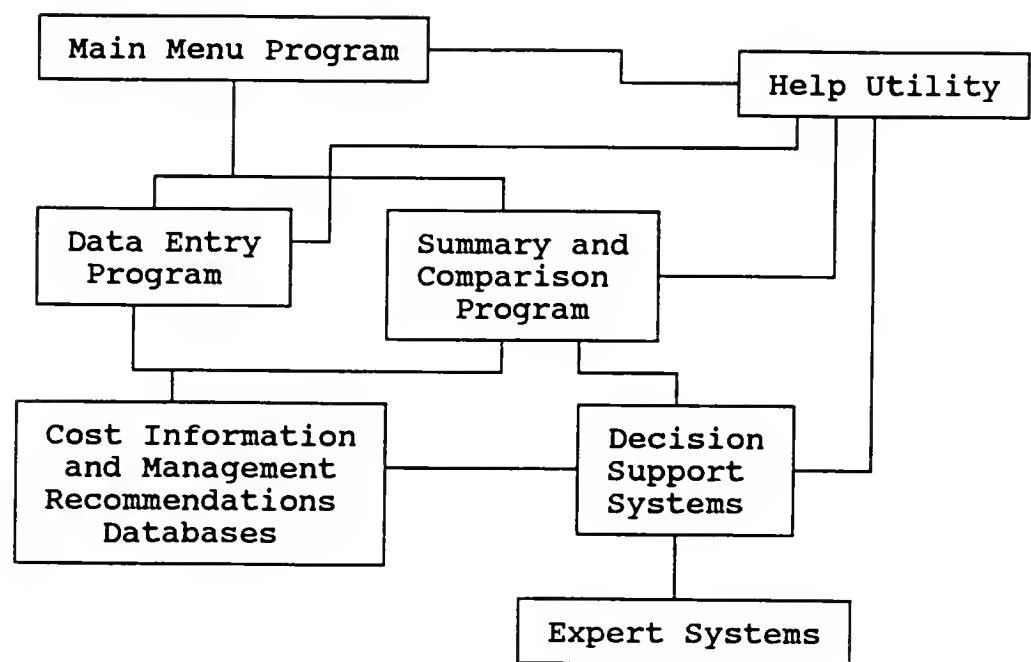


Figure 4-1 COINS Program Structure

storage were designed for maximum flexibility. They allow the user to enter data at various levels of detail based on the amount of cost information available. This is achieved by arranging production cost categories in a hierarchical form. There are ten main cost categories, namely cultivation, dusting, spraying, frost protection, young tree care, irrigation, removing trees, fertilizing, pruning, and other operations. Each category has one or more levels of sub-categories associated with it (Figure 4-2).

The ten main cost categories appear on the first screen of the data entry or summary programs. This level of categories in the hierarchy is referred to by the database as level 1. Each level 1 main cost category has at least one level of sub-categories. These subcategories are referred to as level 2 and level 3. If more detailed information is available on a particular grove practice, the user may expand to a sub-category level and enter or view cost information.

Data Storage

Information on grove characteristics and grove costs are stored in twelve separate data files. One file is specific to grove characteristics, and is used for verifying passwords, ID numbers, and to reference information. Production cost information is stored in eleven main data files; one level 1 file, and ten level 2 files. dBXL data file structures are shown in Appendix A.

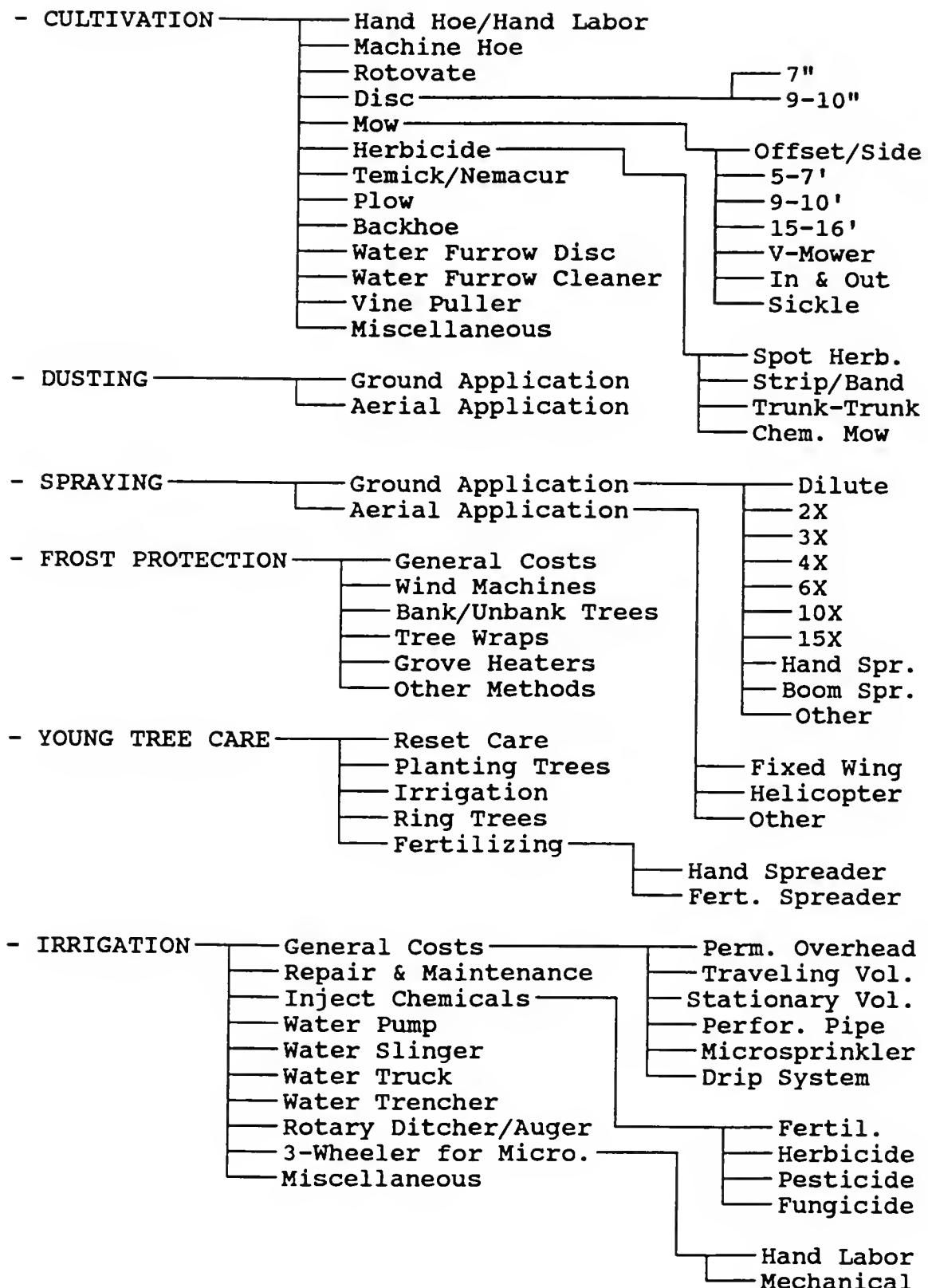


Figure 4-2 Production Cost Hierarchy

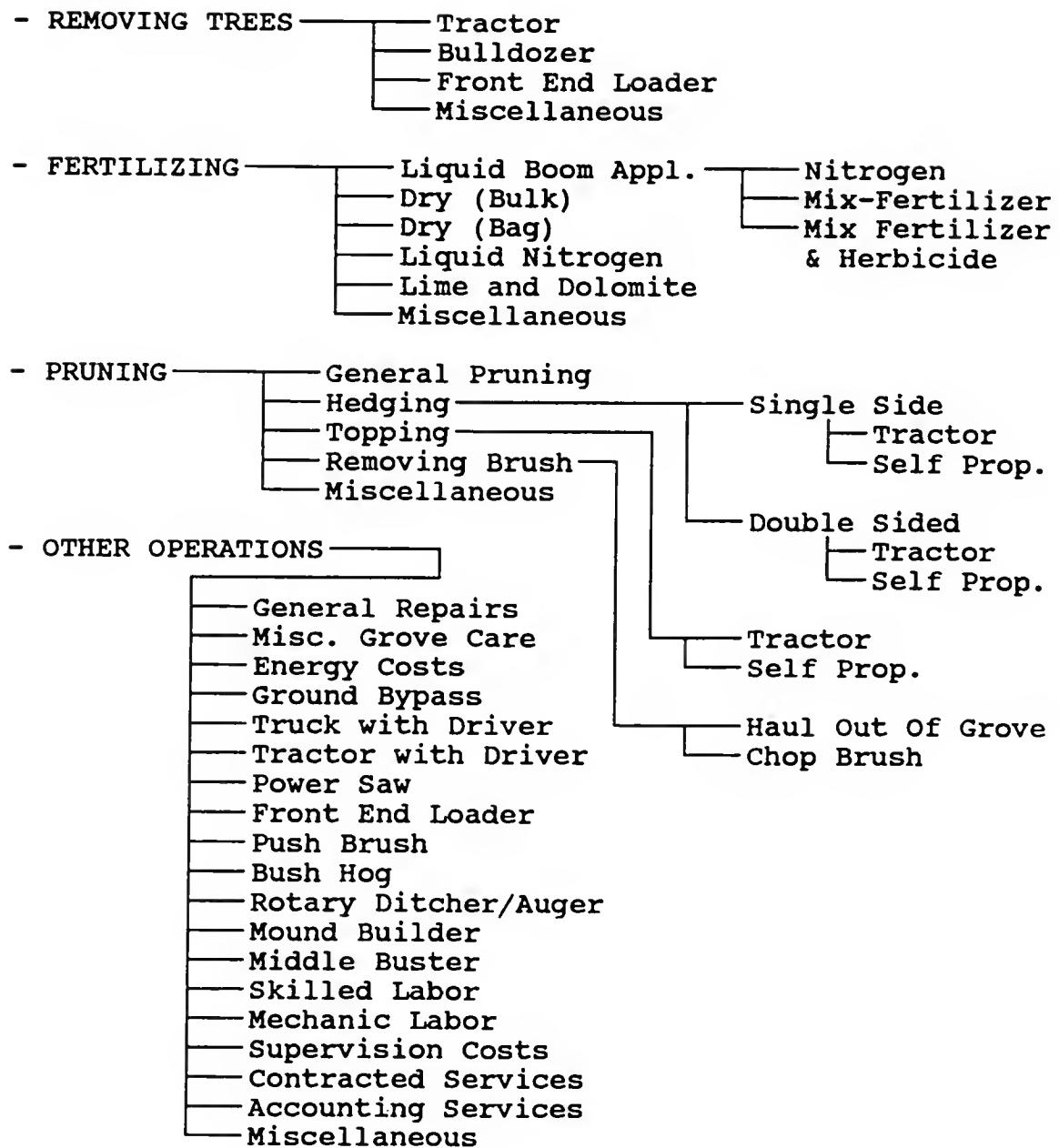


Figure 4-2--Continued

Supporting database files hold information on fruit varieties, grove locations, number of categories and sub-categories, and sub-category locations within the database. Other files include index files and query files. Each cost information data file has a corresponding temporary file. Temporary files are used for data entry and modification, and for data storage after summaries are generated. All user interaction with the database is done through the temporary files. This allows for quicker access, and protects the integrity of the main data files.

When the data entry program is run, appropriate information from the main data files is copied into the temporary files. Hence, if information for a new grove is being entered, information for a grove with costs set to zero (default grove) is copied from each main data file into its corresponding temporary file. Upon completion of data entry and data modification, cost information is appended to the main data files from the temporary files. On the other hand, if information from an existing grove is needed, corresponding cost information for that grove is copied from the main data files into the temporary files, and displayed for editing. When editing is complete, the new information on the grove replaces the old data in the main data files.

Temporary data files are also used when the data summary program is run. Cost information from the main data files for

all groves to be included in the summary is averaged, and the results placed in the temporary files for viewing.

Data Entry Program

Program Design

The data entry program was designed to look and function like a spreadsheet (Figure 4-3). A cursor bar is used to select between ten production cost categories. A menu bar is used to select among ten available functions. Functions are used to access the different features of the program. To select a function, the user moves the cursor bar and presses the enter key. Alternatively, a function may be selected by pressing a specific highlighted character found in each function name. An explanation line below the menu options helps to identify what each function does. The following is an explanation of the ten functions.

Program Functions

Edit. Data is entered using the edit function. When edit is selected, the production category on the highlight bar is highlighted in red, and a help window appears at the bottom of the screen. Costs for labor, machinery, management, and materials may be entered for each category. When the editing is concluded, values in the separate columns are summed, and the results are placed in the overall cost columns. The automatic summation may be suppressed by entering a value for

Variety:Hammins,Valencias. Market:Fresh/Process. ID: 1

Grove Practice	Overall Cost	Labor Cost	Mach. Cost	Mngmt Cost	Material Cost
Cultivation	0.00	0.00	0.00	0.00	0.00
Spraying	0.00	0.00	0.00	0.00	0.00
Dusting	0.00	0.00	0.00	0.00	0.00
Fertilizing	0.00	0.00	0.00	0.00	0.00
Irrigation	0.00	0.00	0.00	0.00	0.00
Removing Trees	0.00	0.00	0.00	0.00	0.00
Pruning	0.00	0.00	0.00	0.00	0.00
Young Tree Care	0.00	0.00	0.00	0.00	0.00
Frost Protection	0.00	0.00	0.00	0.00	0.00
Other Operations	0.00	0.00	0.00	0.00	0.00

New Data File

Edit Help Mode Expand Return Locate Update Comment
 Product Back
 Explanation - Enter costs for this category.

Figure 4-3 Example Initial Data Entry Screen

the overall cost, or by using the mode function explained below.

Help. The data entry program features an on line help utility. When the help function is selected, an options window appears and allows the user to select among several help topics (Figures 4-4a and 4-4b). Help topics include an introduction to the purpose and uses of the program, a short tutorial, an overview of the database structure, an explanation of the ID number to identify groves, and lastly a help utility that explains each function (Figure 4-5). The user may also obtain help on functions by moving the menu bar to the desired function, and pressing the F1 key.

Mode and Update. The mode function allows switching between auto-calculate and manual modes for column summation. When the program starts up, auto-calculate is on, and whenever separate costs for labor, machinery, management, or materials are entered, the program automatically adds these costs, and places the total in the overall column. The user may select manual recalculation in order to enter separate costs for the labor, machinery, management, and materials, as well as a separate overall cost. This feature is important when the user reports partial costs for a category, and the overall cost does not equal the total of the separate costs.

The update function is used to total the costs in the separate columns when mode is set to manual. The user may

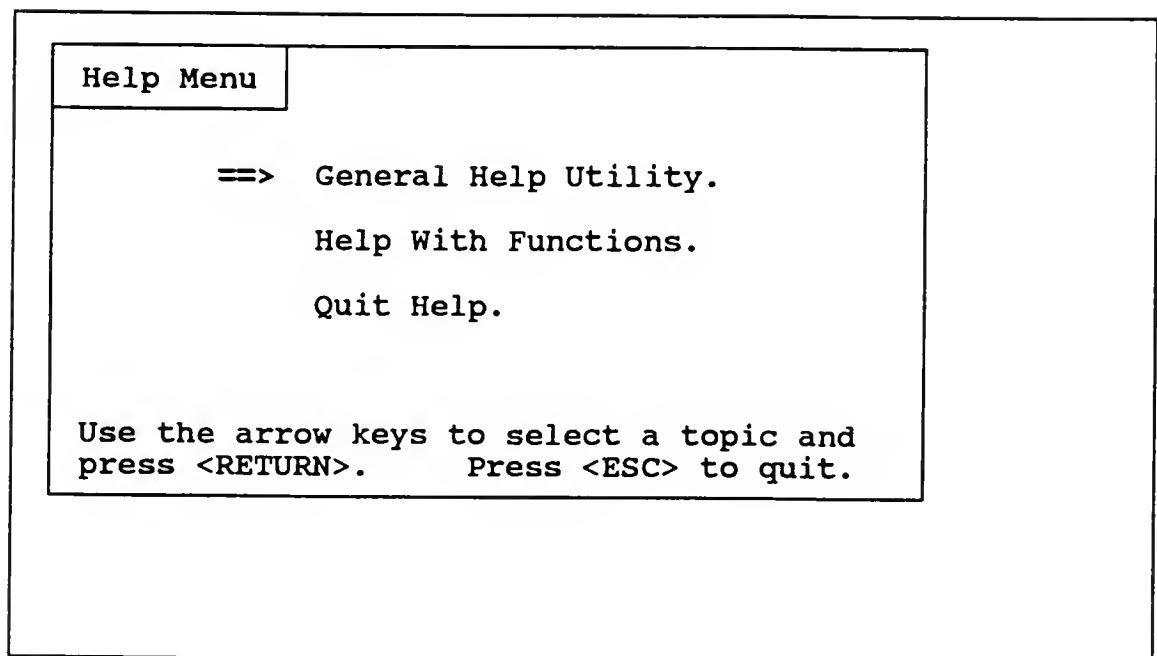


Figure 4-4a Main Help Menu

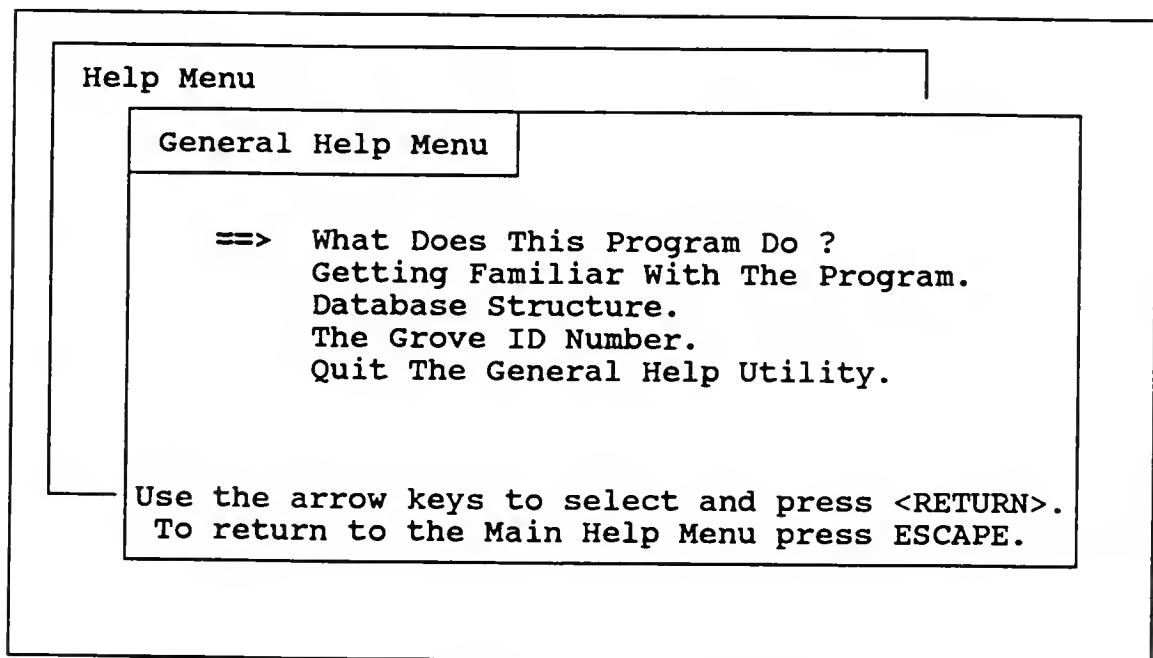


Figure 4-4b General Help Utility Menu

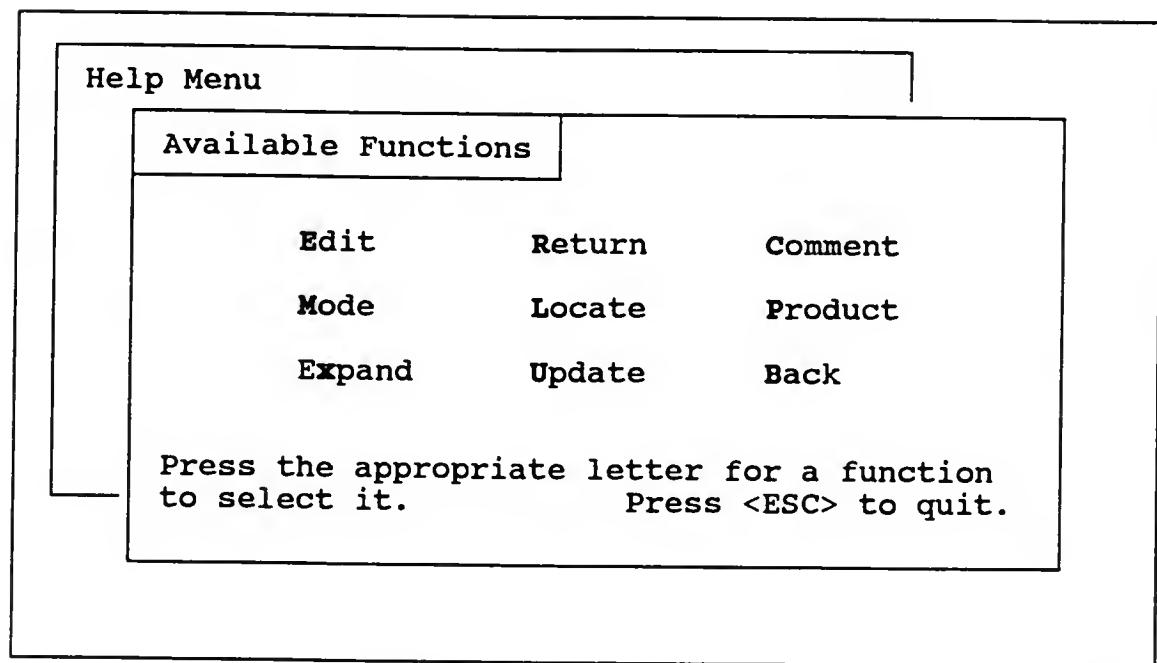


Figure 4-5 Function Help Menu

wish to total all costs, or just those in the current cost category.

Expand and Return. Each of the ten main cost categories is divided into one or more levels of sub-categories. The expand function is used to access the sub-categories for more detailed data entry. The return function allows the user to exit from a sub-category screen and return to a higher level in the hierarchy.

Locate. The locate function serves two purposes. The first is to show a list of sub-categories available for a particular cost category. This serves as a "map" for the operation hierarchy (Figure 4-6). The second usage of the locate function is an index for all grove practices available in the database. This function is used to locate the main category under which a particular grove practice is found. For example, to find the main cost category for 'Energy and Fuel Costs', the user searches through the index for the word mowing. The index will indicate the main category as being 'Other Operations' (Figure 4-7).

Comment and Product. The comment function allows the user to enter a comment for each cost category. Comments may be used as notes or reminders. Similarly, the product feature allows the user to leave a description of the product name, or material name used in a particular grove practice. This feature may be important if the program is expanded to include

View Of Operation Hierarchy		
Level 1	Level 2	Level 3
Cultivation	Hand Hoe/Hand Labor	Offset or Side
Spraying	Machine Hoe	5-7'
Dusting	Rotovate	9-10'
Fertilizing	Disc	15-16'
Irrigation	Mow	V-Mower
Removing Trees	Herbicide	In & Out
Pruning	Temick/Nemacur	Sickle
Young Tree Care	Plow	
Frost Protection	Backhoe	
Other Operations	Water Furrow Disc	
	Water Furrow Cleaner	
	Vine Puller	
	Miscellaneous	

Figure 4-6

Example for the Locate Function for Sub-categories Under the Level 1 Cultivation Category, and Level 2 Mow Sub-category.

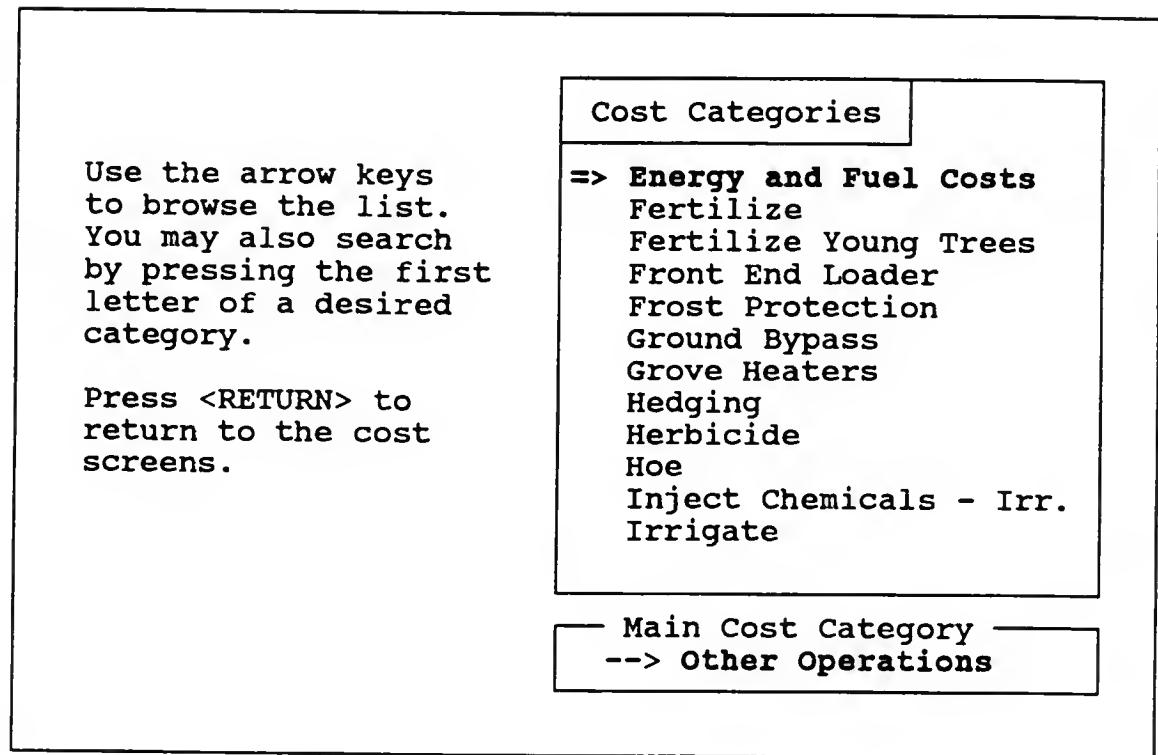


Figure 4-7

Example for the Find Function for Energy and Fuel Costs.

collection of names of pests, weeds, chemicals, or other products used in the citrus operation.

Back. This function is used to return to the COINS main menu. When the back function is used, all the main category files are updated using the costs entered during the session, and control is given to the main menu.

Entering Costs for a Grove

The following section describes the procedure for starting and using the data entry program to input or edit costs for a grove. Three options are available when the program is started. The user may either define and enter costs for a new grove, view or edit information for an existing grove, or delete one of his groves from the database.

Each grove is assigned a grove ID number which is utilized by the user and by COINS to identify the grove. Along with the ID number, a grove can be identified by the user's password. The user must have both the a password and an ID number to enter or edit costs for a grove.

Editing an Existing Grove. If the user chooses to view or edit information for an existing grove, the program displays a menu of ID numbers corresponding to available groves, and prompts for a selection (Figure 4-8). By moving the menu selection bar to each ID number, the characteristics of each grove are displayed. When a grove is chosen, the program searches the database files, retrieves, and displays

the cost information found. It is important to note here, that only those groves associated with the user's own password can be accessed.

Defining a New Grove. To enter costs for a new grove, the user must define the characteristics of the grove. These include size in acres, fruit varieties, fruit market, yield in boxes of fruit, grove location, and grove ID number. A grove definition screen is used to enter the necessary data (Figure 4-9). A list of options is available from which the user selects fruit varieties and grove location (Figures 4-10a and 4-10b). Choosing from a menu of options allows easy selection, and ensures that no discrepancies occur.

Once the information on a grove is complete, the user is prompted to enter a grove ID number. This number is unique to the user's password. Two or more groves with the same ID number may exist as long as they were defined by different users.

Entering and Modifying Data. When the spreadsheet is displayed, the user may enter or change data at any level in the hierarchy. The arrow keys are used to move around the spreadsheet, and a menu bar is used to select the functions described in the previous section. When entry or modification is complete, the data entry program updates all files, and returns control to the main menu.

Deleting Grove Information. Often times a grove is no longer active, or no longer belongs to the person who entered

Florida Citrus Production Cost Survey Program	
Grove Description	
Grove size (acres) ... 5.00	
Variety ... Hamlins, Valencias	
Yield in boxes 3745.00	
Price per Box (\$)..... 6.75	
Grove location Ridge	
Grove ID number 40	
Available Groves	
--->	40
	240
	530
	10

Figure 4-8 Example of Grove Selection Screen for Viewing and Editing Costs

Florida Citrus Production Cost Survey Program	
Grove Description	
Grove size (acres) ...	0.00
Variety ...	Florida
Yield in boxes	0.00
Price per Box (\$)	0.00
Grove location	00000
Grove ID number	0

Figure 4-9 Example Grove Definition Screen

Florida Citrus Production Cost Survey Program	
Grove Description	Options
Grove size (acres) ...	5.00
Variety ...	[REDACTED]
Yield in boxes	0.00
Price per Box (\$) 0.00
Grove location	[REDACTED]
Grove ID number	0
	Hammins Valencias Navel Temples Early/Mid Minneolas Lees Murcotts Novas Marsh Robinsons Duncan

Figure 4-10a Fruit Variety Selection Options

Florida Citrus Production Cost Survey Program	
Grove Description	
Grove size (acres) ...	5.00
Variety ...	Hammins, Valencias
Yield in boxes	2500.00
Price per Box (\$)	7.63
Grove location	██████████
Grove ID number	0
Options	
Ridge	
Interior	
Ind. River	
Southwest	
North	
Central	
Other	

Figure 4-10b Location Selection Options

its costs into the system. A grove may be sold, or in light of the recent freezes, a grove may simply no longer be productive. In such cases the user may wish to remove this grove from the database. When the grove deletion option is chosen, the user needs only to specify the grove ID number, and the program will remove all costs and grove information from the database.

Data Summary and Comparison Program

Program Design

Like the data entry program, the data summary program was designed to look and function like a spreadsheet (Figure 4-11). The main difference between the two programs is that the data summary program does not support any editing features. It is simply a tool for averaging costs, and displaying the results. As in the data entry program, a cursor bar and a menu bar are used to select categories and menu options respectively.

The summary screen provides average per acre costs and returns for the ten main cost categories, as well as both levels of subcategories. Per acre average labor, machinery, management, and material costs are also displayed.

Averaged Annual Per Acre Costs and Returns		Your Grove #: 40	
Cost Item	Range of Costs	Average	Your Grove
Revenue		2786.84	5055.75
Cultivation	76.70 to 194.36	142.26	194.36
Spraying	138.20 to 183.00	167.36	180.88
Dusting	0.00 to 0.00	0.00	0.00
Fertilizing	69.47 to 241.22	173.12	241.22
Irrigation	5.14 to 261.65	169.86	261.65
Removing Trees	0.00 to 1947.98	978.46	1947.98
Pruning	0.00 to 472.70	472.70	0.00
Young Tree Care	71.14 to 270.98	138.48	71.14
Frost Protection	0.00 to 72.08	37.32	2.56
Other Operations	26.55 to 48.44	35.20	26.55
Total Per Acre Expenses		2279.56	2926.34
Per Acre Net Income		507.28	2129.41

Help	Options	Labor	Machinery	Management	Material
Locate	Expand	Return	Back		
Explanation - Access the help utility.					

Figure 4-11 Example Cost Summary Screen

Program Functions

For the purpose of avoiding redundancy, only those options that differ from the data entry program menu will be discussed.

Help. The help option is similar to that in the data entry program, but differs in the contents of the tutorial, and explanation of functions.

Options. This function accesses a decision support system discussed in Chapter IV of this dissertation.

Labor, Machinery, Management, Material. When these options are used, the screen switches from displaying per acre overall costs and returns to a screen showing only the selected separate cost.

Cost Averaging

Li et al. (1990) discuss two major methods of retrieving database information. One is a navigation-based method whereby the user uses a series of menus to travel from one area of the database to another. The second method is the query based access to information. This method uses the users questions to retrieve information. The COINS data summary and comparison program uses the data query method to retrieve the necessary data from the cost databases.

The program requires the user to specify parameters which determine the types of groves that will be used in the summary. Maximum and minimum grove sizes, fruit types, fruit

market (fresh or process), as well as location of the groves must be specified (Figure 4-12). The query may be either very general whereby only one or a few parameters are specified, or very specific. In this way the user can tailor the cost comparison to his own needs and interests. The program also allows the user to specify a grove to compare to the averages. If a grove is specified, per acre costs for that grove will be displayed alongside the averages in the summary screen.

Once the query is defined, the program searches the database for all groves fitting the query and averages the costs found. All overall, labor, machinery, management, and material costs for each category are averaged separately. Data on highest and lowest costs in each category is maintained and later displayed as a range of costs.

The program is designed to carry out a data summary only if three or more groves fit the query. This protects the confidentiality of the data, and prevents the user from "extracting" costs for a single grove in the database by specifying its exact characteristics.

Once the summary screen is displayed, the user may choose to explore the average values in the different levels of the hierarchy as well as view the individual labor, machinery, management, and material per acre costs. A data analysis option allows the user to compare his costs for an operation to the averaged values, and invoke an expert system that aids

Florida Citrus Cost Reporting Program

Grove Information	
Minimum grove size ... 0.00	
Maximum grove size ... 5.00	
Variety ... Any Variety	
Grove location Any Region	
Grove ID number 40	
Cost data is being prepared - Wait	
Groves Found	
Found - 3	
Averages:	
• Size =	
5.00 acres	
• Yield =	
2314.67	
• Price/	
Box =	
\$ 6.02	

Figure 4-12 Example of Query Definition Screen During Data Averaging

in the analysis and gives and management recommendations. The analysis option will be discussed in more detail later.

CHAPTER V
SIMON - SYSTEM FOR INTEGRATING
MANAGEMENT AND COST INFORMATION

A system was developed to integrate management and extension recommendations with production cost information. The System for Integrating Management and Cost Information (SIMON) utilizes an expert system to access a database of management information for a particular grove practice. Based on each recommendation, the system determines an ideal cost for a particular situation and compares that cost to actual expenditures reported by the grower.

The SIMON concept can be applied to many area of the citrus operation, or to other crop systems in addition to citrus. But for the purpose of this project a prototype system was developed to give management recommendations for herbicide application and weed control on citrus. The user defines a weed problem, by identifying categories and names of weeds. These are chosen from a list of weeds commonly associated with citrus. The program then searches a database for appropriate spraying recommendations. The expert system asks the user a series of questions to determine the proper application rates and application times based on conditions particular to his operation. After a herbicide recommendation is given, the user has the option of determining the cost of

controlling the weed problem defined, and making a comparison to costs in his grove. The system may be used in conjunction with the COINS data summary program or as a stand-alone system for citrus herbicide and weed control information.

The following section discusses the herbicide prototype program and the SIMON concept in more detail. System development, program execution, integration with the COINS data summary program, and evaluation will be described.

Program Development

The benefits of an expert system based program for management recommendations give it a clear advantage over traditional methods of conveying management recommendations (Linker, et al.). Information in the system's database can be easily updated with current information on weeds and herbicides. Also, the system can narrow down the number of available recommendations for a particular problem and rank them by order of effectiveness. This greatly reduces extension agents' and grower' time and effort in searching through a long list of recommendations.

There were some advantages to using herbicide application as a grove practice for the prototype system. Herbicide application is a year round operation that must be carried out regardless of exogenous factors such as weather conditions. Also, the number of weeds most commonly associated with citrus, and the herbicides recommended for use on Florida

citrus are limited in number. Some factors such as soil type, severity of weed infestation, and in some cases grove location and rainfall, influence the herbicide application operation. Nagarajan et al. (1987) say that weed management involves a number of strategic and technical decisions, such as chemical control (pre-plant, pre or post emergence) with a choice of chemicals and formulations. But once these factors were identified, almost ideal conditions existed for the development of an expert system based program.

Program Features

The SIMON concept was used in the development of the prototype herbicide program to integrate management recommendations with costs for herbicide application. The program enables the user to abstract an appropriate herbicide recommendation from an information database, given a particular weed problem. A cost information summary is then given to estimate the expenses that may be incurred if the recommendation is followed. The program also serves as a directory, providing information on weeds controlled by each herbicide. Another feature of the program allows the user to compare the effectiveness and related costs of using several herbicides on a particular weed problem.

Program Development Environment

SIMON consists of two segments; a herbicide program which includes the user interface, and an expert system which determines the correct recommendations for herbicide application. The following section discusses the programming environment used for development.

The main herbicide program, like COINS, was written using dBXL's own application development language. Its design targets the novice user with little or no computer experience. To run the program, it is only necessary for the user to follow instructions in a window at the bottom of each screen.

Expert System Environment

Expert System Shells. Expert systems are usually developed using a programming environment called a "shell". Although expert systems can be written in any language, it is often easier and more efficient to use an expert system shell. Shells provide comprehensive environments for the development of rule based expert systems. Expert systems developed using shells utilize an elaborate process of deductive reasoning called an inference engine to arrive at a conclusion from a set of circumstances.

In the case of the expert system portion of SIMON, using a shell would have proved to be somewhat disadvantageous. The program was intended to be distributed to growers in Florida along with the complete COINS system. Most software companies

do not offer unrestricted distribution rights for applications developed using their expert system shells. It is often the case that costly licenses must be purchased for this purpose.

Another disadvantage to using shells was that expert systems must be run through the development environment with which they were written. This increases memory requirements of the programs being run. Also, expert systems usually interact with other supporting programs in order to swap information, and gain access to functions not supported by the shell used for development. For the herbicide expert system, a database environment would have been needed to store cost information and make data queries. Running the expert system separately from its supporting programs would have necessitated the exchange of large amounts of data between the two systems causing a decrease in program efficiency, and requiring an additional amount of memory.

Maintenance of the expert system was a very important factor to consider. Love (1988) discusses that maintenance of the expert system may be quite different from that of the decision support system. If the expertise changes, whether evolutionary or revolutionary, the developers of an expert system must consider methods to help assume that the system's inference is timely. He further states that while the need to provide expert system maintenance is important for all expert systems, it may be particularly appropriate to economics related expert systems. The changing nature of herbicide

formulations, recommendations, and effectiveness on weeds, necessitated high maintenance requirements, and meant that herbicide and weed data needed to be readily accessible, and easily modifiable. It was therefore necessary to ensure that the rules used by the expert system to arrive at recommendations, and the recommendations themselves, were not embedded in the program code. Expert systems developed with shells usually contain all rules and recommendation within the program code, and hence, any changes that need to be made would require the program code to be rewritten and recompiled. This process placed the use of shells at a disadvantage due their inefficient maintenance requirements.

A custom designed expert system environment was used for SIMON. The environment utilizes a unique method of rule storage and inferencing, whereby rules are stored as records in a database. The concept involved is fairly simple, and is flexible enough to be applied to virtually any application requiring a simple rule based expert system.

Environment Advantages. The environment used for SIMON was developed using dBXL, allowing the expert system to be compiled and run in conjunction with the rest of SIMON and the main COINS program. This keeps memory requirements down, and allows license-free distribution of the program. The expert system consists of an algorithm that carries out the simplified inferencing and deduction process, and database files containing rules and recommendations. The two are

completely separate, allowing modifications to be made to the data files independently of the program code. As new or changed information on weeds or herbicides is made available, the data files can be changed by using the dBXL database environment, and requires no revisions to be made to the program code.

Since the expert system part of SIMON is written in dBXL, it is able to take full advantage of dBXL's functions and ability to efficiently and easily manipulate large amounts of information.

Expert System Rule Base

dBXL database files consist of a series of fields and records. Much like a spreadsheet, fields and records can be thought of as columns and rows of information. Rules are stored as records in the database. Each record consists of three main fields (Figure 5-1); rule number, condition, and recommendation fields. Rule numbers for each herbicide are divided into one or more levels of detail allowing easy referencing. The first level of rule numbers is a whole number. Rules with decimal values are the next level rules for a particular condition. File formats for the herbicide and weed guide are shown in Appendix A.

The deduction process involves an iterative process of search and selection until a recommendation is found. First, the expert system displays all condition fields for records

NUMBER	CONDITION	RECOMMENDATION
19.00	Areas receiving more than 20" average annual rainfall	NEXT 19.10
19.00	Areas receiving less than 20" average annual rainfall	NEXT 19.20
19.00	WEED G-H,	Recommendation
19.10	New plantings.	NEXT 19.11
19.10	Non-bearing established plantings.	Recommendation
19.11	Soil texture is coarse.	Recommendation
19.11	Soil texture is medium	Recommendation
19.11	Soil texture is fine	Recommendation
19.20	New plantings.	NEXT 19.21
19.20	Non-bearing established plantings.	Recommendation
19.21	Soil texture is coarse.	Recommendation
19.21	Soil texture is medium. or Soil texture is fine with 2-5% organic matter.	Recommendation
19.21	Soil texture is fine. or Soil has 5-10% organic matter.	Recommendation
19.21	Soil has 2-5% organic matter.	Recommendation
19.21	Soil has 5-10% organic matter.	Recommendation

Figure 5-1 Example Rules Used for the Herbicide Treflan

with first level rule numbers. The user is asked to choose a condition from the list. The recommendation field for the chosen condition will either direct the program to search for another set of conditions, or will contain a recommendation. In the case of the latter, the program terminates the search, and displays the recommendation. If a second set of conditions exist, they are displayed based on their rule numbers, and the user is asked to choose again. This procedure is repeated until the program comes across a recommendation. The program can also accommodate special cases for rules where only a particular situation within a set of rules requires a specific recommendation. This is the case when a particular weed requires a specific or unique recommendation. A flow chart illustrating this deduction process is shown in Figure 5-2.

Knowledge Acquisition

Identifying the Experts

The methods by which the program arrives at management recommendations are based on the thought processes used by experts in the field of weed science and particularly in the area of citrus production. The first step in the design of the program was to identify the experts.

Two citrus herbicide experts were identified. Dr. Megh Singh and Dr. David Tucker are both researchers at the University of Florida's Citrus Research and Education Center

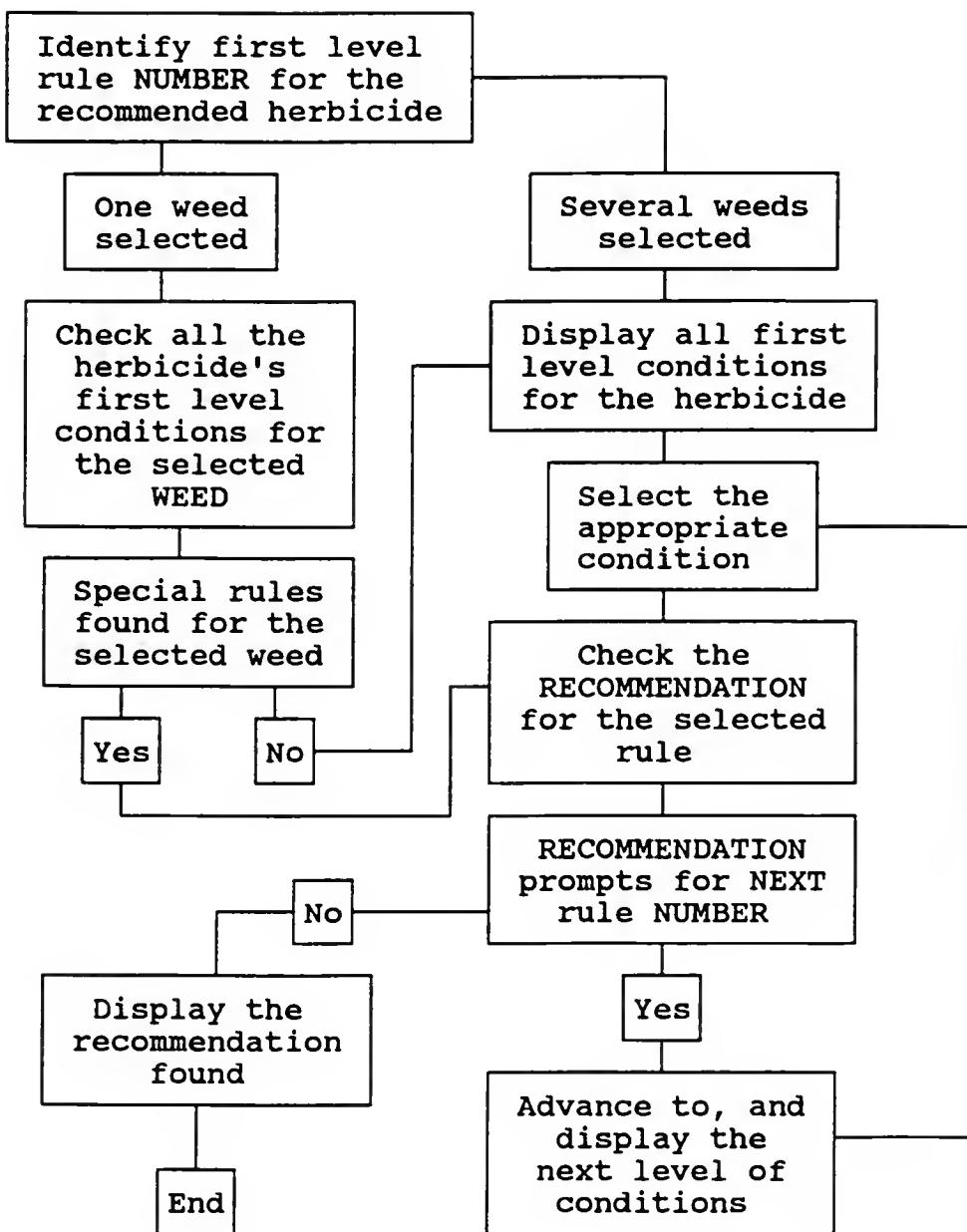


Figure 5-2 Flow Chart Illustrating the Deduction Process Used by SIMON

in Lake Alfred, Florida. Both experts had worked closely with citrus growers and extension agents, and were familiar with situations that may arise concerning weed infestation in citrus. They were also current on developments in the herbicide industry, and hence they provided the complete knowledge required to develop the system. The herbicide and weed guide also relies heavily on published materials for information. However, even with the immense amount of information available in the form of extension guidelines, the actual application of this "domain knowledge" to specific situations had been (and still is) provided primarily by weed specialists (Holt, 1988).

Preliminary Interview

Determining how the experts arrived at a conclusion from a series of circumstances was the next logical step in the program design. Due to the distance between the programmer and the experts, personal interviews were limited to a preliminary interview and several follow up interviews. All other consultations were made over the phone, and through the Institute of Food and Agricultural Sciences' (IFAS) electronic mail system. Beck et al. (1987) mention that in general, extension specialists cannot spend significant portions of their time working on an expert system project. Furthermore the experts and engineers are typically quite distant geographically and cannot meet for intensive interviews on a

regular basis. The purpose of the preliminary interview was to allow the experts to discuss freely the pertinent considerations of the system (Lacey et al., 1989).

During a preliminary interview the experts were given a general idea of the concepts behind COINS. A discussion followed on the steps involved in the development of SIMON, and the herbicide expert system. Requirements and limitations of the herbicide expert system were also discussed. It was determined that only around twenty herbicides were recommended by IFAS for use on Florida citrus. These herbicides were used as the basis for the system's herbicide database. It was also decided that only a certain number of weeds commonly occurred on Florida citrus, and that the weed database should be limited to these weeds.

Sources of Information

Information on weed names and classifications were derived from chemical manufacturers' publications as well as independent studies conducted by the experts and the herbicide manufacturers. A list of herbicides recommended for use on citrus was obtained from the 1990 Citrus Spray Guide (IFAS Publications, 1990).

The expert system rules used to arrive at the proper recommendations were derived from several sources. The main source of the spray recommendations, including rates, scheduling, and other information, was the 1989 Crop

Protection and Chemicals Reference (CPCR). The CPCR contained product labels for all the recommended herbicides. Product labels contain all necessary information needed to use each product, and are used by the grower as a reference. Additional spray recommendations were obtained from the Citrus Spray Guide.

Establishing the Decision Process

It was necessary to establish the thought process that the experts used to analyze a particular weed problem. Following a discussion with the experts a decision tree was drawn up that describes the logic used (Figure 5-3).

The first step involved the definition of a weed problem. Categories as well as names of weeds were selected. Weeds in three categories, namely grasses, broadleaf weeds, and vines, were selected to constitute a weed problem. Weed categories and weed names are listed in Tables 5-1a, 5-1b, 5-1c. The next step was to identify what herbicides control the weeds selected. This is done by referring to the herbicide product labels or the citrus spray guide. If no herbicides were found to control all weeds, the next best herbicides that control as many weeds as possible were selected.

When the herbicides identification process is completed, the herbicides were ranked as to their effectiveness on the weeds selected. The ranking is based on a susceptibility table that was developed by the experts in conjunction with

the chemical manufacturers. It shows the effectiveness of each herbicide on weeds in each category (Table 5-2). The following is an explanation of the five susceptibilities listed in descending order of effectiveness.

S indicates that weeds are susceptible to the herbicide at germination, and at early seedling stage of growth. Weeds may also be susceptible at later stages of maturity.

PS indicates that weeds are susceptible only at germination. Repeat applications may sometimes control established weeds.

I denotes intermediate control indicating that the degree of control will be erratic with some plants within a species population being killed and others not.

T indicates that weeds are tolerant and either showing no signs of injury or able to recover from injury symptoms. U indicates that the susceptibility status is unknown due to lack of experimental data and reliable field observations.

In order to rate the herbicides' effectiveness on a combination of weeds, a rating system was established by the experts and the knowledge engineer. The S, PS, I, T, and U susceptibilities were given equivalent numerical ratings on a scale of one to five, with five being the highest rating corresponding to a susceptibility of S. The ratings for all the weeds selected were summed and resulted in an overall rating for each herbicide.

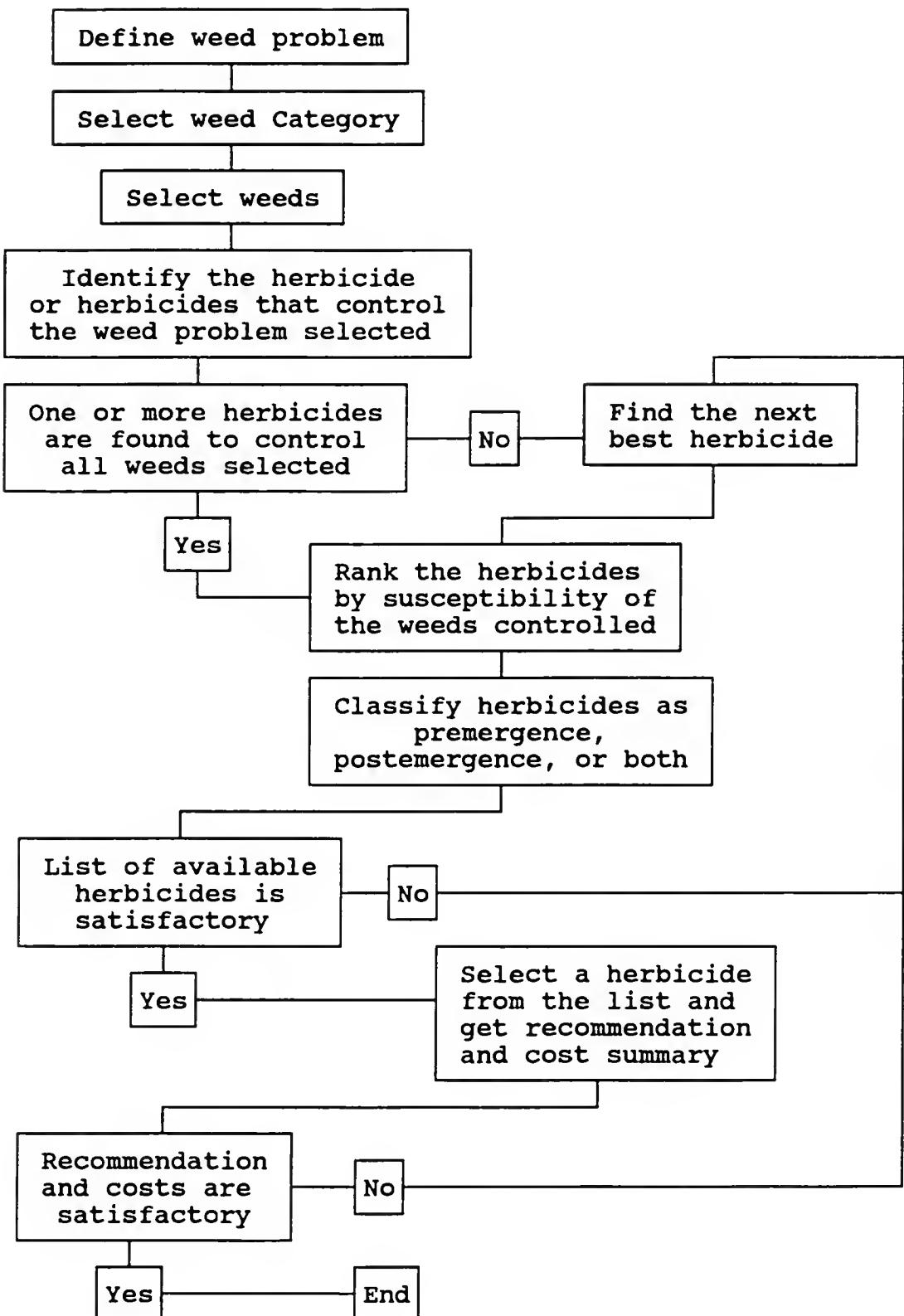


Figure 5-3 Flow Chart for Experts' Decision Process

Table 5-1a List of Weeds by Category. a) grass weeds, b) broadleaf weeds, c) vines

Weed Name	Scientific Name
Bahaigrass	<i>Paspalum notatum</i>
Bermudagrass	<i>Cynodon dactylon</i>
Carpetgrass	<i>Axonopus affinis</i>
Cattail	<i>Typha</i> sp.
Crabgrass	<i>Digitaria adscendens</i>
Crowfootgrass	<i>Dactyloctenium aegyptium</i>
Goosegrass	<i>Eleusine indica</i>
Guineagrass	<i>Panicum maximum</i>
Johnsongrass	<i>Sorghum halepense</i>
Maidencane	<i>Panicum hemitomon</i>
Napiergrass	<i>Pennisetum purpureum</i>
Natalgrass	<i>Rhynchoselytrum repens</i>
Nutsedge	<i>Cyperus rotundus</i>
Pangolagrass	<i>Digitaria decumbens</i>
Paragrass	<i>Panicum purpurascens</i>
Peppergrass	<i>Lepidium virginicum</i>
Sandspur	<i>Cenchrus echinatus</i>
Signalgrass	<i>Brachiaria piligera</i>
Texas Panicum	<i>Panicum Texanum</i>
Torpedograss	<i>Panicum repens</i>
Vaseygrass	<i>Paspalum urvillei</i>
Yellow Foxtail	<i>Setaria glauca</i>

Table 5-1b List of Weeds by Category. a) grass weeds, b) broadleaf weeds, c) vines

Weed Name	Scientific Name
Bitter Mint	<i>Hyptis mutabilis</i>
Black Nightshade	<i>Solanum Nigrum</i>
Brazilian Pepper	<i>Schinus terebinthifolius</i>
Camphorweed	<i>Heterotheca subaxillaris</i>
Ceaserweed	<i>Urena lobata</i>
Common Purslane	<i>Portulaca oleracea</i>
Common Ragweed	<i>Ambrosia artemisiifolia</i>
Creeping Charlie	<i>Lippia nodiflora</i>
Cudweed	<i>Gnaphalium sp.</i>
Dayflower	<i>Commelina benghalensis</i>
Dogfennel	<i>Eupatorium capillifolium</i>
Evening Primrose	<i>Oenethora sp.</i>
Flat-topped Goldenrod	<i>Euthamia minor</i>
Florida Beggarweed	<i>Desmodium tortuosum</i>
Florida Pusley	<i>Richardia scabra</i>
Goatweed	<i>Scoparia dulcis</i>
Goldenrod	<i>Solidago sp.</i>
Horseweed	<i>Conyza canadensis</i>
Jerusalem Oak	<i>Chenopodium botrys</i>
Lambsquarters	<i>Chenopodium album</i>
Lantana	<i>Lantana camara</i>
Mexican Tea	<i>Chenopodium ambrosioides</i>
Pepperweed	<i>Lepidium virginicum</i>
Pigweed	<i>Amaranthus sp.</i>
Pokeberry	<i>Phytolacca americana</i>
Primrose Willow	<i>Ludwigia peruviana</i>
Rouge Plant	<i>Rivina humilis</i>
Rustweed	<i>Polyppodium procumbens</i>
Saltbush	<i>Baccharis halimifolia</i>
Seamyrtle	<i>Baccharis halimifolia</i>
Skunkweed	<i>Achyranthes aspera</i>
Sowthistle	<i>Sonchus sp.</i>
Spanish Needles	<i>Bidens pilosa</i>
Spurge	<i>Chamaesyce hyssopifolia</i>
Swampwillow	<i>Salix nigra</i>
Teaweed	<i>Sida acuta</i>
Virginia Pepperweed	<i>Lepidium virginicum</i>
Waxmyrtle	<i>Myrica cerifera</i>

Table 5-1c List of Weeds by Category. a) grass weeds, b) broadleaf weeds, c) vines

Weed Name	Scientific Name
Air Potato	<i>Dioscorea bulbifera</i>
Balsam Apple Vine	<i>Momordica charantia</i>
Bigroot Morningglory	<i>Ipomoea pandurata</i>
Brazilian Nightshade	<i>Solanum seaforthianum</i>
Briars	<i>Smilax</i> sp.
Calico Vine	<i>Aristolochia littoralis</i>
Cats Claw Vine	<i>Bignonia unguis-cati</i>
Cypress Vine	<i>Ipomoea quamocilt</i>
Maypop (Passion Flower)	<i>Passiflora incarnata</i>
Milkweed (Strangler) Vine	<i>Morrenia odorata</i>
Moonvine	<i>Ipomoea alba</i>
Morningglory	<i>Ipomoea</i> sp.
Narrow-Leaf Milkweed Vine	<i>Cynanchum scoparium</i>
Peppervine	<i>Ampelopsis arborea</i>
Rosary Pea	<i>Abrus precatorius</i>
Virginia Creeper	<i>Parthenocissus</i> <i>quinquefolia</i>
Wild Grape	<i>Vitis rotundifolia</i>
Wild Watermelon (Citron)	<i>Citrullus vulgaris</i>
Woenvine	<i>Cassytha filiformis</i>

Table 5-2 Weed Susceptibilities

Weed Name	Herbicide Codes ^a									
	A	B	C	E	F	G	H	I	J	
Bahaiagrass	S	S	S	I	U	T	S	T	U	
Bermudagrass	PS	PS	PS	T	U	S	S	T	U	
Common Carpetgrass	S	S	S	I	U	U	S	T	U	
Cattail	U	U	U	U	U	U	S	T	U	
Crabgrass	S	S	S	S	U	S	S	S	S	
Crowfootgrass	S	S	S	S	U	PS	S	S	U	
Goosegrass	S	S	S	S	U	S	S	S	S	
Guineagrass	PS	PS	PS	PS	U	S	S	S	U	
Johnsongrass	PS	PS	PS	PS	U	S	S	PS	PS	
Maidencane	PS	PS	PS	PS	U	U	S	U	U	
Napiergrass	T	T	T	T	U	S	S	U	U	
Natalgrass	S	S	S	PS	U	U	S	U	U	
Purple Nutsedge	I	I	I	T	U	T	PS	PS	U	
Pangolagrass	S	S	S	I	U	U	S	T	U	
Paragrass	S	S	S	I	U	S	S	PS	U	
Southern Sandspur	S	S	S	S	U	S	S	PS	U	
Hairy Signalgrass	PS	PS	PS	I	U	S	S	PS	U	
Texas Panicum	S	S	S	U	U	S	S	PS	U	
Torpedograss	PS	PS	PS	T	U	I	PS	T	U	
Vaseygrass	PS	PS	PS	T	U	S	S	T	U	
Yellow Foxtail	S	S	S	S	U	S	S	PS	I	
Peppergrass	U	U	U	U	U	U	U	U	U	
Florida Beggarweed	S	S	S	U	U	T	S	T	U	
Bitter Mint	S	S	S	U	U	T	S	U	U	
Black Nightshade	S	S	S	S	U	T	S	PS	U	
Brazilian Pepper	U	U	U	U	U	T	I	T	U	
Cesarweed	U	S	S	S	U	T	S	U	U	
Camphorweed	S	S	S	S	U	T	S	U	U	
Common Purslane	S	S	S	S	U	T	I	T	S	
Common Ragweed	S	S	S	PS	U	T	S	PS	I	
Creeping Charlie	S	S	S	U	U	T	I	T	U	
Cudweed	S	S	S	U	U	T	S	PS	S	
Dayflower	S	S	S	S	U	T	PS	T	U	
Dogfennel	PS	PS	PS	PS	U	T	S	T	U	
Evening Primrose	U	U	U	U	U	T	S	T	U	

^a. The letters correspond to the following herbicides

A. Bromacil	F. EPTC
B. Bromacil & Diuron	G. Fluazifop-Butyl
C. Bromacil & Diuron	H. Glyphosate
E. Diuron	I. Metolcholor
	J. Napropamide

Table 5-2--Continued

Weed Name	Herbicide Codes ^a									
	A	B	C	E	F	G	H	I	J	
Florida Pusley	S	S	S	PS	U	T	S	T	I	
Flat-Topped Goldenrod	PS	PS	PS	PS	U	T	S	T	U	
Goatweed	T	S	PS	PS	U	T	I	U	U	
Goldenrod	PS	PS	PS	PS	U	T	S	T	U	
Horseweed	U	U	U	U	U	T	S	U	U	
Jerusalem Oak	PS	PS	PS	I	U	T	PS	T	U	
Lambsquarters	S	S	S	PS	U	T	S	PS	S	
Lantana	PS	PS	PS	PS	U	T	S	T	U	
Mexican Tea	U	U	U	U	U	U	U	U	U	
Pepperweed	S	S	S	S	U	T	S	T	U	
Pigweed	T	PS	S	S	U	T	S	PS	S	
Pokeberry	S	S	S	PS	U	T	S	U	U	
Primrose Willow	U	S	S	U	U	T	S	U	U	
Rouge Plant	S	S	S	PS	U	T	U	U	U	
Rustweed	S	S	S	U	U	T	U	U	U	
Saltbush	T	T	T	T	U	T	S	T	U	
Seamyrtle	U	U	U	U	U	T	S	T	U	
Skunkweed	PS	PS	PS	PS	U	T	U	U	U	
Sowthistle	U	S	S	U	U	T	S	T	U	
Spanish Needles	T	S	PS	S	U	T	S	T	U	
Spurge	S	S	S	PS	U	T	S	T	U	
Swampwillow	U	U	U	U	U	T	S	T	U	
Teaweed	PS	S	PS	PS	U	T	PS	T	U	
Virginia Pepperweed	S	S	S	U	U	T	S	PS	U	
Waxmyrtle	U	U	U	U	U	T	I	T	U	
Air Potato	T	T	T	T	U	T	PS	T	U	
Balsam Apple Vine	PS	S	S	PS	U	T	S	T	U	
Bigroot Morningglory	T	U	T	U	U	T	PS	T	U	
Brazilian Nightshade	U	U	U	U	U	T	S	T	U	
Briars	T	T	T	T	U	T	I	T	U	

^a. The letters correspond to the following herbicides

A. Bromacil	F. EPTC
B. Bromacil & Diuron	G. Fluazifop-Butyl
C. Bromacil & Diuron	H. Glyphosate
E. Diuron	I. Metolchlor
	J. Napropamide

Table 5-2--Continued

Weed Name	Herbicide Codes ^a									
	A	B	C	E	F	G	H	I	J	
Calico Vine	U	U	U	U	U	T	I	T	U	
Cat'S Claw Vine	T	T	T	T	U	T	PS	T	U	
Cypress Vine	U	U	U	U	U	T	S	T	S	
Maypop	PS	PS	PS	I	U	T	S	T	U	
Milkweed (Strangler) Vine	PS	PS	PS	PS	U	T	I	T	U	
Moonvine	I	I	I	T	U	T	U	T	U	
Morningglory	PS	PS	PS	PS	U	T	S	T	S	
Narrow-Leaf Milkweed Vine	T	T	T	T	U	T	I	T	U	
Peppervine	T	T	T	T	U	T	I	T	U	
Rosarypea	PS	PS	PS	PS	U	T	S	T	U	
Virginia Creeper	T	T	T	T	U	T	PS	T	U	
Wild Grape	T	T	T	T	U	T	I	T	U	
Wild Watermelon	U	PS	PS	U	U	T	S	T	U	
Woevine	T	T	T	T	U	T	U	T	U	

^a. The letters correspond to the following herbicides

A. Bromacil	F. EPTC
B. Bromacil & Diuron	G. Fluazifop-Butyl
C. Bromacil & Diuron	H. Glyphosate
E. Diuron	I. Metolchlor
	J. Napropamide

Table 5-2--Continued

Weed Name	Herbicide Codes ^a								
	K	L	M	N	O	P	Q	T	PS
Bahaiagrass	PS	PS	T	I	PS	U	T	PS	
Bermudagrass	PS	PS	T	I	PS	I	T	PS	
Common Carpetgrass	I	S	U	I	S	U	T	T	S
Cattail	PS	T	U	S	U	U	T	T	
Crabgrass	S	S	I	PS	S	U	S	S	
Crowfootgrass	PS	S	I	PS	S	U	S	S	
Goosegrass	PS	S	I	S	S	S	S	S	
Guineagrass	PS	S	I	S	S	U	PS	S	
Johnsongrass	PS	PS	I	PS	S	PS	PS	PS	
Maidencane	PS	T	U	T	U	U	T	T	
Napiergrass	PS	PS	U	I	PS	U	T	PS	
Natalgrass	PS	PS	I	U	PS	U	I	PS	
Purple Nutsedge	I	T	I	T	T	U	T	T	
Pangolagrass	PS	PS	I	PS	PS	U	T	PS	
Paragrass	PS	PS	U	T	PS	U	T	PS	
Southern Sandspur	PS	S	I	S	S	U	I	S	
Hairy Signalgrass	PS	S	U	S	S	U	PS	S	
Texas Panicum	PS	S	I	S	S	S	I	S	
Torpedograss	S	PS	I	T	PS	U	T	PS	
Vaseygrass	PS	PS	U	PS	PS	U	T	PS	
Yellow Foxtail	PS	S	I	S	S	S	S	S	
Peppergrass	U	U	U	U	U	U	U	U	
Florida Beggarweed	PS	T	I	S	T	U	S	T	
Bitter Mint	I	T	U	U	U	U	U	T	
Black Nightshade	PS	T	S	I	T	U	S	T	
Brazilian Pepper	U	T	U	I	T	U	T	T	
Ceasarweed	U	T	U	U	U	U	U	T	
Camphorweed	I	T	PS	PS	T	U	U	T	
Common Purslane	S	S	S	S	S	U	S	S	
Common Ragweed	PS	T	I	S	T	U	S	T	
Creeping Charlie	U	T	I	S	T	U	S	T	
Cudweed	PS	T	PS	S	T	U	S	T	
Dayflower	PS	T	I	S	T	U	T	T	
Dogfennel	S	T	U	PS	T	U	PS	T	
Evening Primrose	I	T	PS	T	T	U	I	T	

^a. The letters correspond to the following herbicides

K. Norflurazon	O. Pendimethalin
L. Oryzalin	P. Sethoxydim
M. Oxyfluorfen	Q. Simazine
N. Paraquat Dichloride	T. Trifluralin

Table 5-2--Continued

Weed Name	Herbicide Codes ^a								
	K	L	M	N	O	P	Q	T	
Florida Pusley	PS	S	S	S	S	U	I	S	
Flat-Topped Goldenrod	PS	T	U	U	T	U	U	T	
Goatweed	PS	T	U	U	T	U	I	T	
Goldenrod	PS	T	PS	T	T	U	S	T	
Horseweed	I	T	T	PS	T	U	I	T	
Jerusalem Oak	I	T	PS	PS	T	U	T	T	
Lambsquarters	PS	S	S	S	S	U	S	S	
Lantana	T	T	T	I	T	U	T	T	
Mexican Tea	U	U	U	U	U	U	U	U	
Pepperweed	PS	T	S	PS	T	U	I	T	
Pigweed	I	S	S	S	S	U	S	S	
Pokeberry	PS	T	U	PS	T	U	S	T	
Primrose Willow	PS	T	U	PS	U	U	U	T	
Rouge Plant	U	T	U	U	U	U	U	T	
Rustweed	I	T	U	U	U	U	U	T	
Saltbush	I	T	PS	PS	T	U	T	T	
Seamyrtle	I	T	U	PS	U	U	T	T	
Skunkweed	U	T	U	U	U	U	U	T	
Sowthistle	I	T	S	S	T	U	S	T	
Spanish Needles	I	T	PS	S	T	U	S	T	
Spurge	S	S	PS	S	S	U	S	S	
Swampwillow	U	T	PS	PS	T	U	T	T	
Teaweed	PS	T	S	T	T	U	I	T	
Virginia Pepperweed	PS	S	S	PS	U	U	I	S	
Waxmyrtle	U	T	U	PS	T	U	T	T	
Air Potato	U	T	U	U	U	U	T	T	
Balsam Apple Vine	PS	T	PS	PS	T	U	S	T	
Bigroot Morningglory	I	T	U	PS	T	U	S	T	
Brazilian Nightshade	I	T	U	T	T	U	S	T	
Briars	T	T	U	PS	T	U	T	T	

^a. The letters correspond to the following herbicides

K. Norflurazon	O. Pendimethalin
L. Oryzalin	P. Sethoxydim
M. Oxyfluorfen	Q. Simazine
N. Paraquat Dichloride	T. Trifluralin

Table 5-2--Continued

Weed Name	Herbicide Codes ^a								
	K	L	M	N	O	P	Q	T	
Calico Vine	U	T	U	PS	U	U	T	T	
Cat'S Claw Vine	U	T	U	T	U	U	T	T	
Cypress Vine	I	T	PS	PS	T	U	T	T	
Maypop	T	T	PS	PS	T	U	T	T	
Milkweed (Strangler) Vine	PS	T	PS	PS	T	U	PS	T	
Moonvine	U	T	PS	PS	U	U	T	T	
Morningglory	PS	T	S	PS	T	U	I	T	
Narrow-Leaf Milkweed Vine	U	T	U	PS	T	U	U	T	
Peppervine	U	T	U	PS	U	U	T	T	
Rosarypea	U	T	U	U	U	U	T	T	
Virginia Creeper	U	T	U	PS	T	U	T	T	
Wild Grape	T	T	U	PS	T	U	T	T	
Wild Watermelon	I	T	PS	S	T	U	T	T	
Woevine	T	T	U	U	U	U	U	T	

^a. The letters correspond to the following herbicides

K. Norflurazon	O. Pendimethalin
L. Oryzalin	P. Sethoxydim
M. Oxyfluorfen	Q. Simazine
N. Paraquat Dichloride	T. Trifluralin

Apart from the susceptibility ratings, herbicides were classified into three categories. Pre-emergence herbicides which are used prior to weed emergence to control potential problems. Post-emergence herbicides which are used to control established weeds. And lastly herbicides that offer both pre-emergence and post-emergence control. The classification is used to determine which types of herbicides are suited for a particular situation.

After rating and classifying the herbicides, a selection among alternatives was made. The experts agreed that once all recommended herbicides have been presented to the user, it is up to that user to choose which herbicide to utilize. They were not willing to specify a particular herbicide to a grower to avoid showing any type of support or endorsement for one product.

Following the selection of a herbicide, recommendations for spraying rates were given based on information found in the product labels. In most cases more than one recommendation was listed depending on such factors as types of weeds, soil moisture conditions, and soil type. The final recommendation depended on these factors. Spraying cost estimates were then given based on recommended spray rates, product costs, and treated acreage.

Follow-up Interviews

Two follow-up interviews were conducted throughout the program development process. The program was evaluated by the experts at each follow-up interview with special emphasis on the new features added since the last interview. Ideas on improvements and enhancements were exchanged. During the final follow-up interview, a complete list of program features was established, and updates on herbicide and weeds information were made. Once all enhancements and features in the list were carried out, the final version of the program was ready for evaluation.

Program Execution

The program proceeds in one of three ways: a herbicide recommendation is given based on a weed problem, a list of weeds controlled by a herbicide is identified, or two or more herbicides are compared as to their effectiveness on a weed problem.

Obtaining a Herbicide Recommendation

The user defines a weed problem by choosing weeds from lists in the grass, broadleaf, and vine categories. The program searches for herbicides that control the weeds selected. If one or more herbicides are found to control all weeds selected, they are ranked and displayed on the screen (Figure 5-4). If no herbicides are found to control all weeds

Herbicide and Weed Guide**Available Herbicides for All Weeds Selected**

Trade Name	Common Name	Rating	Effect.
Roundup	Glyphosate	6	Post
Devrinol	Napropamide	6	Pre
Solicam	Norflurazon	7	Pre
Goal	Oxyfluorfen	6	Both
Gramoxone	Paraquat Dichloride	8	Post

Susceptibility Rating - The susceptibility rating is a measure of the effectiveness of each herbicide on the weed combination it controls. It is the sum of the susceptibilities of each weed to the herbicide.

Figure 5-4 Example List of Herbicides Available to Control The Defined Weed Problem

Herbicide and Weed Guide

Note - No herbicides were found that control all weeds selected.

The program can now proceed in two different ways:

- 1 - The program will search for herbicides that control as many weeds as possible from the list of selected weeds. One herbicide is selected from a list, and recommendations and spraying information are given for that herbicide.
- 2 - The program will search for individual herbicides for grass weeds, broadleaf weeds, and vines. Herbicides that control as many weeds as possible in each category are found. A herbicide is selected for each category, and recommendations and spraying information are given for each herbicide.

Figure 5-5

Option Screen When One Herbicide is Not Found to Control All the Weeds Selected

selected, the user is prompted to direct the program in one of two ways (Figure 5-5). The program can search for the best herbicide for all weeds selected, or the best herbicides for weeds in each category. Once herbicides have been identified, the user may either select a herbicide, or reject the choices, and direct the program to search for the next best alternatives. The search continues until the user accepts a herbicide and requests a recommendation. If herbicides are recommended separately for each category of weeds, a combination of two or more herbicides must be used. The program only lists these herbicides and the individual spray rates for each. It does not give information on mixing procedures, compatibility, and precautions. The user must refer to more detailed information by consulting the product labels.

Recommendations for all herbicides are stored in a database, and with the aid of the expert system and some input from the user, the appropriate recommendation for the selected herbicide is given (Figure 5-6). At this point in the program, a cost estimate for the selected herbicide can be obtained. The total cost for spraying the herbicide at the recommended rate reflects the material costs for using the herbicide. Other costs are usually incurred during the operation such as machinery, labor, and management costs. The cost per unit of purchasing the herbicide and number of treated acres to be sprayed are required from the user. If

Hyvar X - (Bromacil) for use on Texas Panicum**Recommendation**

Apply 4-5 lbs. of HYVAR X per acre during the period from winter to early summer. Alternatively, make two applications of 3-4 lbs. per acre per year in spring and summer. Partial control usually occurs with a single treatment; repeat applications are required to control perennial weeds. Control of perennial weeds may be improved by cultivation prior to treatment; otherwise, avoid working the soil as long as weed control continues since effectiveness may be reduced.

Susceptibility - Susceptible at germination and early seedling stage of growth. May also be susceptible at later stages of maturity.

Figure 5-6

Example Recommendation Screen for Using Hyvar X Herbicide on Texas Panicum

Herbicide Cost Information - Krovar I

Cost per gallon for this herbicide (\$) - 7.35
Number of treated acres to be sprayed - 5.00

Rates in pounds per treated acre -
Recommended range - 2.00 - 4.00
Recommended maximum - 8.00

Total Cost (\$) - Range per treated acre - 14.70 - 29.40
Range for this grove - 73.50 - 147.00

Maximum Cost (\$) - Per treated acre - 58.80
For this grove - 294.00

Figure 5-7 Example Cost Screen for Krovar I Herbicide

additional spray material such as oils or surfactants are to be used, the user must specify the cost of these materials. When all information is provided, the program calculates the cost per acre and total grove cost for the herbicide based on the recommendation and the user's inputs (Figure 5-7).

Obtaining a List of Weeds Controlled by a Herbicide

The user chooses a herbicide from a list of all herbicides in the database (Table 5-3). The program searches for weeds controlled by that herbicide and provides lists of weeds in the grass, broadleaf, and vine categories. The user may select any weed from the lists and obtain appropriate spraying recommendations and cost information.

Comparing Several Herbicides

It is often the case that a grower has several choices of herbicides to use on his weed problem. It is very difficult to assess the advantages of using one herbicide over another. An accurate management decision could lead to a reduction in costs of spraying while maintaining an acceptable level of weed control. A feature of the program allows a comparison to be made between several herbicides resulting in a better management decision. Their effectiveness on a particular weed problem as well as the cost of using each herbicide are compared. After selecting the herbicides from a list, and defining a weed problem, a summary screen is displayed for

Table 5-3 List of Herbicides Recommended for Use on Florida Citrus

Trade Name	Common Name
Hyvar X/L	Bromacil
Krovar I	Bromacil & Diuron
Krovar II	Bromacil & Diuron
Karmex, Direx	Diuron
Eptam	EPTC
Fusilade	Fluazifop-Butyl
Roundup	Glyphosate
Dual	Metolachlor
Devrinol	Napropamide
Solicam	Norflurazon
Surflan	Oryzalin
Goal	Oxyfluorfen
Gramoxone	Paraquat Dichloride
Prowl	Pendimethalin
Poast	Sethoxydim
Princep	Simazine
Treflan	Trifluralin

each selected herbicide. The user is required to go through the spraying recommendations and cost information portions of the program to gather all the necessary data. Once recommendations and costs for the herbicides have been gathered a comparison can be made using the summary screens. Each summary (Figure 5-8a) contains information on the number of weeds controlled by a herbicide (Figure 5-8b), weeds not controlled, and cost per acre as well as total cost for the grove.

Integration with COINS

The herbicide and weed guide can be accessed either from the main menu of COINS or through the summary and comparison program. If the user wishes to compare his herbicide application costs with costs for recommended rates, the herbicide and weed guide must be accessed through the summary program. From the summary program, the user runs the herbicide and weed guide to obtain application recommendations and associated costs. Overall and material costs from the summary program are then displayed alongside the recommended rates and costs (Figure 5-9). The user may then evaluate his herbicide application operation and make management decisions based on differences in herbicides, rates, and associated costs.

Herbicide Summary	Number of Herbicides Selected - 2
--------------------------	--

1. Fusilade - Fluazifop-Butyl

Number of weeds controlled - 4 of 13

Cost Information -

Total Cost -

Range per treated acre - 30.19 - 40.25

Range for this grove - 150.94 - 201.25

2. Roundup - Glyphosate

Number of weeds controlled - 6 of 13

Cost Information -

Total Cost -

Range per treated acre - 18.30 - 73.20

Range for this grove - 91.50 - 366.00

Maximum Cost - Per treated acre - 192.15

For this grove - 960.75

Figure 5-8a Example Summary Screens for Comparing Fusilade and Roundup Herbicides

Herbicide Summary	Number of Herbicides Selected - 2
--------------------------	--

Roundup - Glyphosate on Combination Of Weeds

Weeds Not Controlled	Type
Bahaigrass	Grass
Bermudagrass	Grass
Guineagrass	Grass
Bitter Mint	Broadleaf
Black Nightshade	Broadleaf
Brazilian Pepper	Broadleaf
Cudweed	Broadleaf

Figure 5-8b Example of Seven Weeds Not Controlled By Roundup

Herbicide Cost Information - Krovar I

Cost per gallon for this herbicide (\$) - 7.35
Number of treated acres to be sprayed - 5.00

Rates in pounds per treated acre -
 Recommended range - 2.00 - 4.00
 Recommended maximum - 8.00

Total Cost (\$) - Range per treated acre - 14.70 - 29.40
 Range for this grove - 73.50 - 147.00

Maximum Cost (\$) - Per treated acre - 58.80
 For this grove - 294.00

Total Herbicide Costs for Grove #40 (\$) -
 Overall Cost - 356.00
 Material Cost - 227.13

Figure 5-9 Example Cost Screen for Krovar I Herbicide
Including Grower Overall and Material Costs

CHAPTER VI TESTING AND EVALUATION

The performance of the COINS system was tested and evaluated during the developmental stages and again at the completion of the project. The testing and evaluation process involved two major phases. The first phase involved debugging the system and testing its performance with real data. The purpose of this phase, termed operational evaluation, was to determine whether or not the system performed according to design standards, and requirements. The second phase of the evaluation involved determining the system's qualifications as an information and management tool for the Florida citrus industry. This phase, termed professional evaluation, was carried out by allowing a group of Florida citrus growers, extension specialists, county agents, and citrus specialists to utilize and evaluate the system. Evaluation results are shown in tables 6-1 and 6-2.

Phase 1 - Operational Evaluation

Testing and Evaluation of the COINS Cost Programs

Preliminary Testing and Debugging. When COINS was being developed, cost information was needed to test the various routines that constituted the data entry and summary programs.

A data set was created from the published reports of caretaker charges to mock actual grower cost data. The cost information generated was not accurate, and was used only to debug the programs and test the functionality of routines within the programs.

Testing COINS With Actual Data. New application programs must be thoroughly debugged against "real" data (Harrington, 1988). One of the prime sources for accidental destruction of data in a database is the testing and use of new application programs that have not been thoroughly debugged.

In order to properly test the overall performance of the COINS programs, actual cost information was needed. Within the constraints of time and resources, it was decided that an initial group of ten growers would be contacted. The names of ten potential participants was drawn up from a list of growers and citrus cooperatives that had already expressed an interest in working with information systems, by taking part in the FAIRS program (Florida Agricultural Information Retrieval System). Phone contact was made with the growers in order to explain the purpose of the project, and to solicit cooperation. Arrangements to visit the growers were made. Six of the ten growers contacted, agreed to participate in a short information session that included a demonstration of the program, and a brief explanation of the overall objectives of the project. Two of the ten expressed no desire to help with the project due to lack of time, and two growers agreed to

look over an information package on the project rather than sit in on a meeting. Written information packages containing an explanation of the project objectives, and two cost survey forms were mailed out to each of the two growers.

Following the information sessions, written cost survey packets were mailed out to two growers, a citrus cooperative, and a caretaker operation that also maintained grove records for customers. Through these final four participants, production cost information for 50 groves was collected.

Each of the two growers supplied information on one of their groves by filling out the written survey, the citrus cooperative supplied information on two groves through a computer printout of costs, and the caretaker operation supplied cost information for 46 groves belonging to several customers, by downloading the necessary data from an IBM System 36 to a 3.5" floppy disk. The data was transferred using a utility that converted data from the IBM System 36 software package being used by the caretaker to a file in DBASE III+ format.

The cost information supplied by the growers and cooperative was entered into the COINS database through the data entry program. Information supplied by the caretaker operation was stored in two data files on disk. The first file held information on grove characteristics, and was easily appended to the COINS database with a few modifications. The second file held the actual cost data for the grove. A hard

copy of this information was made and used to input the information into COINS through the data entry program. Since the grove characteristics were not entered by hand in this case, this data collection method proved to be time efficient. However, the cost information file could not be appended directly to the COINS databases due to discrepancies in the names of some cost categories. For this reason manual entry of the cost data was needed.

Some categories were modified during data entry in order to accommodate the different category names used by the growers. Also, additional categories not covered by the original caretaker surveys were added. It was estimated that data entry took approximately 10 to 15 minutes per grove to complete.

Testing and Evaluation of the Herbicide and Weed Guide

All rules used to reach recommendations were derived from the herbicide product labels and hence were very accurate. For this reason evaluation of these rules was not necessary. It was, however, necessary to evaluate the procedures the program used to arrive at its conclusions. The purpose of the evaluation was to determine whether the program properly goes through the logic steps used by the experts to reach a recommendation. The accuracy of the recommendations (i.e. which herbicide to use), and not the spraying rates and herbicide information, were also evaluated.

The completed version of the herbicide and weed guide was demonstrated to the experts for final evaluation. All program features were demonstrated and several runs were carried out to test the various functions. Following the evaluation, the experts agreed that the program ran all the applications satisfactorily. The experts carried out several runs to match their recommendations with those of the program. It is important to note here that a final recommendation for a herbicide is often given based on the user's choice from a list of recommended herbicides. The experts cannot make the choice for the user. The program's ability to obtain accurate lists of appropriate herbicides beginning with a weed problem, was also found to be acceptable by the experts.

The program in its final form was also installed on one of the experts' computers for further evaluation. The purpose of this evaluation was to determine what future modifications and enhancements could be made to the program.

Phase 2 - Professional Evaluation

Role of Trade Show Exhibit

The main concern prior to the professional evaluation was to recruit enough growers and citrus industry professionals to use and evaluate the system. Success with phone solicitation was found to be limited due to the growers' lack of full knowledge of the system's capabilities. Most growers contacted cited lack of time and limited computer expertise as

the principal problems when declining to participate in the evaluation.

It was decided that the best way to obtain participation would be to demonstrate the program to a group of growers, showing its potential benefits and usefulness as a management tool. COINS was demonstrated at a citrus trade show in Lakeland, Florida. The trade show is held every year and is attended by thousands of citrus industry professionals, including vendors, growers, caretakers, managers, college professors, and extension specialists. A booth was set up at the show with a demonstration version of COINS. Those interested in the program were asked to sit through a five minute demonstration that outlined the COINS system's capabilities. Following the demonstration, they were given a two page information pamphlet with brief details on the main purpose, features, and requirements of the system (Appendix B). The second page of the information sheet was a software order form. It indicated that the software was available free of charge on a trial basis in exchange for an evaluation of the system. Those interested in ordering the software were asked to fill out the order form and mail it in, or simply leave it at the exhibit table. Information required from the participants included name, address, phone number, and best times to be contacted. It was also important to get information on the type of computer and floppy disk drive that will be used to install and run the system.

The exhibit and demonstrations were very successful. Approximately thirty people stopped by the booth for information during a two day period. The demonstration was found to be an effective tool in generating enthusiasm, and arousing interest in COINS. Short discussions followed some demonstrations where participants gave their views and comments on the COINS system.

Citrus growers, and operation managers living in various regions of Florida, the United States, and some foreign countries expressed an interest in receiving a copy of COINS. Several specialists and citrus industry professionals also expressed interest in examining and evaluating the system. Those included a former county agent, a professor of citrus at South Florida Community College, two professors of the Fruit Crops Department at the University of Florida, a citrus researcher and economics specialist at the University of Florida's Citrus Research and Education and Center, and a professor at the Department of Food and Resource Economics.

Role of Citrus and Extension Specialists

The main purpose of COINS was to provide information to citrus growers as well as other professionals in the citrus industry. Hence, program evaluation by extension and citrus specialists was important, and provided a different perspective.

Extension specialists and county agents helped provide additional names of growers that were potential users of the system. These growers were contacted, and those interested, were mailed the COINS software package.

Purpose of the Evaluation Form

The evaluation form (Appendix B) used was designed to serve two purposes. The first was to evaluate the usefulness of the program's features as decision tool, and to evaluate COINS overall functional performance as a software package. The form was divided into structured responses, whereby the evaluator rated a certain aspect of the program's usefulness or performance, and non-structured responses which were aimed at determining strong points and possible improvements.

Evaluation Procedures

Evaluations were carried out using two methods. The software was either mailed out to participants along with a cover letter, a quick reference guide and an evaluation form (Appendix B), or a demonstration and evaluation session was set up with the participant at his or her convenience. When growers were involved, it was more beneficial for them to receive the software by mail and evaluate it on their own time. This also allowed the program to be tested completely by the grower avoiding any bias to the evaluation by having an

expert user present, as in the case with the information session.

Software Sent by Mail. The software was mailed out on either two 720K 3½" diskettes or three 360K 5½" floppy diskettes. Transferring the COINS system from the distribution diskettes required little or no computer knowledge. An install program that transferred all the necessary files to a sub-directory on the user's hard disk drive was included with the program.

The program itself uses approximately 5 megabytes of hard disk space. Up to an additional 5 megabytes of hard disk space were required during cost averaging due to the use of temporary files for data storage. The exact amount of additional memory required depended on the number of groves being averaged. In order to reduce the number of files and hence diskettes required to mail to participants, a special program was used to compress the required programs into special archived files. The install program creates a COINS sub-directory on the users hard drive and copies the compressed files to it. The install program then decompresses the archived files on the hard drive, thus creating the full running version of COINS.

The quick reference guide (Appendix B) was included with the software package. It contained all information necessary to install, and run the program. The user was asked to

evaluate the program by returning the completed evaluation forms that were also included in the packages.

Personal Contact Sessions. Personal contact sessions with growers and other specialists were used as a means of evaluating COINS. Meetings included a detailed demonstration of COINS followed by a discussion and evaluation. During the meetings COINS was installed on the participant's computer. Each of the two cost programs were demonstrated using examples from the database to show cost information for groves. The herbicide and weed guide was also demonstrated thoroughly with specific examples.

During the discussion that followed the demonstration, participants were encouraged to comment on positives and negatives aspects of the system. At the conclusion of the meeting, the participants were given the COINS quick reference guide, and asked to contact the programmer in case of any problems. They were also provided with a COINS software request form to give to any persons interested in receiving the program.

Evaluation Results for Structured Responses

Frequency of Use. The herbicide and weed guide received the highest ratings for frequency of use. The cost summary and comparison program was used frequently, and the data entry program less frequently.

Rating of General Aspects. The quick reference guide provided all necessary information for the installation and execution of all program features. System installation was rated as excellent. The quality, contents, and context sensitivity of the help utilities was rated as good. General ease of use of the system was rated as good, and improved with increased use of the programs.

The speed with which the programs access information was found to be satisfactory with the exception of the cost averaging process that takes place before summaries are displayed. This part of the program involves lengthy data compilation and calculations as well as frequent hard disk access, and hence requires considerably longer to run than other applications.

Data Entry Program Evaluation. Grove definition parameters namely grove size, type of fruit, yield, price per box, fruit varieties, fruit market (fresh, processed, or both), and grove location where found to constitute an acceptable description for a grove. Other parameters were suggested as possible additions to the existing ones. These were tree spacing or tree set, tree count per acre, year of production, general weather conditions and occurrences of unusual weather patterns during the growing season, average age of the grove, location of bodies of water near the groves, and the nature of each grove operations (contracted out, or performed by the grower).

The data entry program was found to be useful for storing cost information, but did not replace existing packages that specialized in grove accounting. The rating for thoroughness and usefulness of the cost categories and sub-categories varied among growers. Those growers who kept records of detailed costs found the sub-categories to be useful during data entry. Lack of detailed costs for many groves was found to decrease the usefulness of the sub-categories in the summary and comparison program.

Usefulness of menu options was rated as good. And the program as a whole was found to be relatively easy to use. The user interface including, menu driven functions and screens, help menus, and the spreadsheet type data entry screens were rated as excellent.

Summary and Comparison Program Evaluation. Search parameters were found to be fairly comprehensive, and allowed flexibility in determining the types and amount of information to be summarized. Some additional search parameters were recommended such as year of production, average age of the grove, general condition and quality of trees, and weather conditions during the particular growing season. In general the program was found to be easy to use, and usefulness of menu functions was rated a good.

Averaged data provided in the summaries was found to be a good source of production cost information. Accuracy of the cost data was a major concern, but it was established that the

cost information was to be used only as a general indicator of industry averages. Comparisons between industry averages and grower costs were found to be very useful. The comparisons were found to give a general idea of how a grower's expenses compared to industry averages. However, the accuracy of the comparisons depended on the specificity of the data summary parameters given at the start of the summary program. The more general the parameters, the less accurate the comparison data.

The program was reported to aid citrus growers in determining possible problem areas in their operations. The summary column for the growers' own operations was a helpful indicator of per grove costs and revenues. It was suggested that a grower be able to compare several years of production for his own operation in order to study trends and potential problems. This may be achieved by incorporating a year of production parameter when collecting the grove costs. In conclusion, the cost summary and comparison program was found to be an effective aid for management decision making.

Herbicide and Weed Guide Evaluation. The general ease of use of the herbicide and weed guide was rated as good. Although the program offers no help screens, the menu driven user interface was found to be adequate. Thoroughness of herbicide and weed lists was rated as excellent. Growers normally referred to the Florida Citrus Spray Guide for information and lists of recommended herbicides. The program

comprised a comprehensive and easily accessible source of information. Lists of weeds controlled by each herbicide and subsequent recommendations were useful.

The program was found to be an excellent tool for obtaining herbicide recommendations. Arriving at a herbicide recommendation from a set of circumstances was found to be highly useful. The recommendations given by the program were not very detailed but supplied the necessary information on spray rates.

In many cases, growers are faced with making a decision on which herbicide to purchase from several vendors bidding for his business. Or, the program may recommend several choices of herbicides to be used on weed problem. The ability to compare the herbicides was found to be particularly useful as a decision making tool.

The usefulness of the integration of the spraying rates with material cost estimates was rated as good. Cost summaries for herbicide recommendations and for herbicide comparisons, along with printed reports constituted a comprehensive decision making tool for weed control on citrus.

Information Sharing. One of the major concerns since the beginning of this project has been the reluctance of growers to share their cost information. The main strategy used to overcome this potential problem was ensuring the confidentiality and integrity of cost data. A password system was developed to protect the integrity of files. Sources of

cost information distributed to growers were blanketed by using an identical password for all groves. Also, no less than three groves can be averaged to produce a summary. All these safety features were explained to the evaluation participants. Most growers who evaluated the system indicated they would have no problem sharing their data as long as confidentiality was ensured.

Evaluation Results for Non-structured Responses

The results of the non-structured evaluation yielded favorable results. The program's main strengths were in its ability to store and retrieve useful production cost information. The system provided growers with a means to evaluate their operation's performance and gain valuable insight into possible problem areas. Information sharing in the form of cost data as well as extension and management recommendations were also listed as program strengths. The herbicide and weed guide was found to be a particularly useful decision making tool.

Some recommendations were made for the overall improvement of COINS. It was suggested that more grove definition parameters be added. An increase in the total number of groves in the system, and the areas covered by the survey was also desired. The inclusion of cost information for several growing seasons and the ability to compare those costs was suggested by some growers as a possible enhancement

to the program. More accurate comparison criteria were also recommended. And finally, it was suggested that decision support systems cover other areas in addition to the herbicide category.

Table 6-1 Responses to Written Evaluations

Responses	Statements/Questions ^a		
	1	2	3
Frequently	1	0	4
Sometimes	3	4	2
Rarely	2	2	0
Total	6	6	6

^a. The numbers correspond to the following statements

1. Extent of use of the data entry program.
2. Extent of use of the summary and comparison program.
3. Extent of use of the herbicide and weed guide.

Table 6-1 -- Continued

Responses	Statements/Questions ^a				
	1	2	3	4	5
Excellent	4	4	0	0	1
Good	2	1	3	5	4
Fair	0	1	2	1	1
Poor	0	0	1	0	0
Total	6	6	6	6	6

^a. The numbers correspond to the following statements

Rating for general aspect of COINS.

1. Ease of installation
2. Directions for use
3. Overall speed of accessing information
4. General ease of use of programs
5. Quality and usefulness of help utility

Table 6-1 -- Continued

Responses	Statements/Questions ^a						
	1	2	3	4	5	6	7
Excellent	1	1	0	0	0	1	3
Good	4	2	6	4	6	4	2
Fair	1	3	0	2	0	1	1
Poor	0	0	0	0	0	0	0
Total	6	6	6	6	6	6	6

^a. The numbers correspond to the following statements

Rating for characteristics of the data entry program.

1. Thoroughness of grove definition parameters
2. Usefulness as a data entry and storage tool
3. Thoroughness of cost categories
4. Usefulness of sub-categories
5. Thoroughness of sub-categories
6. Usefulness of menu functions
7. General ease of use of program

Table 6-1 -- Continued

Responses	Statements/Questions ^a						
	1	2	3	4	5	6	7
Excellent	0	0	0	0	0	0	3
Good	3	3	3	2	3	6	1
Fair	3	3	3	3	1	1	0
Poor	0	0	0	1	2	0	0
Total	6	6	6	6	6	6	6

^a. The numbers correspond to the following statements

Rating for the characteristics of the summary and comparison program.

1. Thoroughness of search parameters
2. Usefulness as an information tool
3. Usefulness as a cost comparison tool
4. Usefulness as a decision making tool
5. Usefulness of information to your operation
6. Usefulness of menu functions
7. General ease of use of program

Table 6-1 -- Continued

Responses	Statements/Questions ^a									
	1	2	3	4	5	6	7	8	9	10
Excellent	2	3	2	3	1	0	1	1	2	2
Good	4	3	3	3	5	5	2	4	3	3
Fair	0	0	1	0	0	1	0	1	0	1
Poor	0	0	0	0	0	0	0	0	1	0
Total	6	6	6	6	6	6	3	6	6	6

^a. The numbers correspond to the following statements

Rating for characteristics of the herbicide and weed guide.

1. Thoroughness of list of herbicides
2. Thoroughness of list of weeds
3. Usefulness of herbicide recommendations
4. Usefulness of comparing several herbicides
5. Usefulness in showing weeds controlled by a herbicide
6. Usefulness of cost information on herbicides
7. Usefulness of printed reports
8. Usefulness as a decision making tool
9. Usefulness of information to your operation
10. General ease of use of program

Table 6-2 Estimated Responses to Discussions

Responses	Statements/Questions ^a		
	1	2	3
Frequently	0	0	3
Sometimes	2	3	0
Rarely	1	0	0
Total	3	3	3

^a. The numbers correspond to the following statements

1. Extent of use of the data entry program.
2. Extent of use of the summary and comparison program.
3. Extent of use of the herbicide and weed guide.

Table 6-2 -- Continued

Responses	Statements/Questions ^a				
	1	2	3	4	5
Excellent	4	0	0	0	2
Good	1	5	2	5	2
Fair	0	0	2	0	1
Poor	0	0	1	0	0
Total	5	5	5	5	5

^a. The numbers correspond to the following statements

Rating for general aspect of COINS.

1. Ease of installation
2. Directions for use
3. Overall speed of accessing information
4. General ease of use of programs
5. Quality and usefulness of help utility

Table 6-2 -- Continued

Responses	Statements/Questions ^a						
	1	2	3	4	5	6	7
Excellent	0	0	0	0	0	0	1
Good	1	3	5	3	5	5	4
Fair	4	2	0	2	0	0	0
Poor	0	0	0	0	0	0	0
Total	5	5	5	5	5	5	5

^a. The numbers correspond to the following statements

Rating for characteristics of the data entry program.

1. Thoroughness of grove definition parameters
2. Usefulness as a data entry and storage tool
3. Thoroughness of cost categories
4. Usefulness of sub-categories
5. Thoroughness of sub-categories
6. Usefulness of menu functions
7. General ease of use of program

Table 6-2 -- Continued

Responses	Statements/Questions ^a						
	1	2	3	4	5	6	7
Excellent	0	0	0	1	0	0	0
Good	0	4	3	2	0	4	5
Fair	4	1	2	2	3	1	0
Poor	1	0	0	0	0	0	0
Total	5	5	5	5	3	5	5

^a. The numbers correspond to the following statements

Rating for the characteristics of the summary and comparison program.

1. Thoroughness of search parameters
2. Usefulness as an information tool
3. Usefulness as a cost comparison tool
4. Usefulness as a decision making tool
5. Usefulness of information to your operation
6. Usefulness of menu functions
7. General ease of use of program

Table 6-2 -- Continued

Responses	Statements/Questions ^a									
	1	2	3	4	5	6	7	8	9	10
Excellent	4	3	5	2	1	2	0	0	0	4
Good	1	2	0	3	2	3	2	5	3	1
Fair	0	0	0	0	2	0	0	0	0	0
Poor	0	0	0	0	0	0	0	0	0	0
Total	5	5	5	5	5	5	2	5	3	5

^a. The numbers correspond to the following statements

Rating for characteristics of the herbicide and weed guide.

1. Thoroughness of list of herbicides
2. Thoroughness of list of weeds
3. Usefulness of herbicide recommendations
4. Usefulness of comparing several herbicides
5. Usefulness in showing weeds controlled by a herbicide
6. Usefulness of cost information on herbicides
7. Usefulness of printed reports
8. Usefulness as a decision making tool
9. Usefulness of information to your operation
10. General ease of use of program

CHAPTER VII CONCLUSIONS AND RECOMMENDATIONS

The primary objective of this dissertation was to provide citrus growers in Florida with a means of improving their production practices through the enhancement of knowledge and management decision making, by providing an economic basis for extension and management recommendations. This goal was successfully achieved by developing and integrating a computer based citrus production cost information system with extension and management recommendations. The techniques used have allowed the dissemination of valuable knowledge among citrus growers in Florida. It has helped create a dynamic source of citrus production cost information.

The utilization of a database management environment provided a comprehensive method for the development of an information system that is both dynamic and flexible. The environment allowed for the efficient manipulation of large amounts of information in a way that facilitates maintenance and information updating.

A system that collects and summarizes citrus production costs for groves in Florida was designed and developed. The Citrus Production Cost Information System (COINS) allows comparisons to be made between individual grove costs and

industry averages. Information retrieval can be customized to include a wide or narrow information domain.

A herbicide and weed guide was designed and developed as a prototype for a system that integrates production cost information with extension and management recommendations (SIMON). The decision support system incorporates an expert system that uses rules to arrive at management recommendations. The expert system was designed to utilize a unique method of deduction and information storage that allows easy access to rules and data, allowing efficient maintenance and updating.

COINS was tested using real grove cost information from fifty individual groves in Florida. System evaluation yielded encouraging responses from citrus growers who installed and used the system on their own computers. Evaluations were also carried out by citrus specialists, county agents, consultants, and extension specialists. The concept of a dynamic database of cost information integrated with extension and management recommendations can be used to enhance communication of information among citrus growers in Florida. The concepts used in the herbicide and weed guide may be applied to other areas of the citrus operation, and the overall concept of the COINS system can be applied to virtually any agricultural operation.

Some recommendations to further strengthen COINS as a decision support system for citrus production costs are discussed below.

1) The prototype system developed to demonstrate the SIMON concept currently deals with the herbicide operation. The development of other systems to handle other production areas such as pesticide application, irrigation, fertilization, and frost protection would complement the existing system.

2) When defining a grove, the user provides information on size, yield, price per box, type of fruit, fruit market, and grove location. The addition of such criteria as tree spacing, tree count per acre, average age of the grove, nature of operation (contracted out or performed by the grower), and types of chemicals used, would allow for a more comprehensive description of a grove. It would also allow for more accurate comparisons with the industry averages to be made.

3) Production costs are currently compared on a same year basis. The COINS database would be greatly enhanced with the inclusion of data for more than one growing season. Such information would allow comparisons to be made over several years of production.

4) COINS is currently designed to reside on a growers computer. All necessary files and programs are located on his system. With a growing database, and the need for more efficient maintenance, the possibility of an on-line system

whereby COINS is located at a central location with users accessing the system through modems should be explored.

5) The integration of COINS with other agricultural information systems would greatly enhance the systems capabilities as a tool for agricultural technology transfer.

6) The transfer of information from source to user has an endless potential for growth and improvement. The COINS system is currently available for citrus growers in Florida. The concepts discussed in this dissertation should be implemented in other areas of agriculture.

APPENDIX A
DATABASE FILE FORMATS

File format for production cost files:

<u>Field</u>	<u>Field Name</u>	<u>Type</u>	<u>Length</u>	<u>Dec</u>	<u>Description</u>
1	OPERATION	Character	20		Operation name
2	ID	Numeric	5		Grove ID number
3	OVERALL	Numeric	9	2	Overall cost
4	LABOR	Numeric	8	2	Labor cost
5	MACHINERY	Numeric	8	2	Machinery cost
6	MANAGEMENT	Numeric	8	2	Management cost
7	MATERIAL	Numeric	8	2	Material cost
8	LEVEL	Numeric	1		Level in hierarchy
9	COMMENT	Character	60		Comment
10	PRODUCT	Character	60		Product description
11	SEPARATE	Logical	1		Separate cost access
12	OVERRANGE	Character	24		Overall cost range
13	LABORANGE	Character	24		Labor cost range
14	MACHRANGE	Character	24		Machinery cost range
15	MANARANGE	Character	24		Management cost range
16	MATERANGE	Character	24		Material cost range
17	GROWERCODE	Character	20		Password

File format for weed files:

<u>Field</u>	<u>Field Name</u>	<u>Type</u>	<u>Length</u>	<u>Description</u>
1	NAME	Character	40	Weed name
2	SCINAME	Character	40	Scientific name
3	CODE	Character	2	Herbicide code
4	SELECT	Logical	1	Selection flag
5	TYPE	Character	1	Classification

Files format for herbicide file:

Field	Field Name	Type	Length	Dec	Description
1	NAME	Character	30		Herbicide name
2	TRADE	Character	30		Trade name
3	HCODE	Character	2		Herbicide code
4	NUMBER	Numeric	5	2	Herbicide number
7	BROAD	Logical	1		Controls broadleaf
8	BNAME	Character	60		Broadleaf codes
9	GRASS	Logical	1		Controls grasses
10	GNAME	Character	60		Grass codes
11	VINE	Logical	1		Controls vines
12	VNAME	Character	60		Vine codes
14	PRICE	Numeric	6	2	Price (not used)
15	UNIT	Character	3		Price unit
16	FLAG	Logical	1		Selection flag
17	PICK	Logical	1		Selection flag
18	EFFECT	Character	4		Effectiveness

Files format for herbicide recommendations file:

Field	Field Name	Type	Length/Dec	Description
1	NAME	Character	30	Herbicide name
2	TRADE	Character	30	Trade name
3	NUMBER	Numeric	5 2	Rule number
4	CONDITION	Character	60	First condition
5	LINK	Character	5	Linker (AND, OR)
6	CONDITION2	Character	60	Second condition
7	RECOM1	Character	254	First recommendation
8	RECOM2	Character	254	Second recommendation
9	NOTE1	Character	254	Special note
10	NOTE2	Character	254	Special note
11	FLAG	Logical	1	Selection flag
12	UNIT	Character	4	Unit(lbs.,qts.,gal.)
13	LOW	Numeric	6 2	Low application rate
14	HIGH	Numeric	6 2	High application rate
15	MAX	Numeric	6 2	Maximum rate
16	OTHER	Numeric	6 2	Other chemical
17	ALTERNATE	Logical	1	Second recommendation
18	NUMALT	Numeric	1	Number of application
19	ALOW	Numeric	6 2	Low application rate
20	AHIGH	Numeric	6 2	High application rate
21	AMAX	Numeric	6 2	Maximum rate
22	AOTHER	Numeric	6 2	Other chemical needed
23	MAXN	Numeric	2	Maximum number of applications

**APPENDIX B
SYSTEM EVALUATION**

**University of Florida
Agricultural Engineering Department**

COINS - Citrus Cost Information System

Purpose: COINS is a computer program designed to provide industry average citrus production costs. It also features decision support systems for various operations. A herbicide and weed guide is currently available.

Features:

- **Data Entry** - A series of spreadsheets allow you to store production cost information for your grove in ten categories: cultivation, dusting, spraying, frost protection, young tree care, irrigation, tree removal, fertilizer application, pruning, and other operations. Costs may be entered for several different groves at varying levels of detail.
- **Data Retrieval** - You give a description of grove size, type of fruit, and location, and the program will retrieve information for all available groves that fit the description.
- **Cost Summary** - Information found in the data retrieval program is averaged, and then displayed in a per acre costs and returns summary. You may also do an on screen comparison between the averages and costs for one of your groves.
- **Herbicide and Weed Guide** -
 - Displays a list of weeds controlled by a particular herbicide.
 - Compares the effectiveness of two or more herbicides on a particular weed problem.
 - Gives herbicide recommendations for weed problems, including spraying information and application rates.
 - Gives a summary of costs associated with applying a herbicide.

Requirements:

The programs require an IBM compatible microcomputer with 640K of RAM memory, a hard disk drive, and a color monitor. COINS requires at least 5 Megabytes of free hard disk space. The Herbicide and Weed Guide requires at least 500K of free hard disk space. The program can run on any IBM compatible PC, XT, AT or 386, but execution on slower machines may be very time consuming.

University of Florida
Agricultural Engineering Department

COINS - Citrus Cost Information System

COINS is currently being tested and is available free of charge to Florida citrus growers. To receive a copy of COINS, including the data entry, retrieval, and summary programs as well as the Herbicide and Weed Guide, simply fill out this form and mail it to:

Ramzi Khuri
Agricultural Engineering Department
Frazier Rogers Hall
University of Florida
Gainesville, FL 32611
Tel. (904) 392-5979

After receiving your form, I will contact you and set up a one or two hour demonstration session in your office involving a demonstration and evaluation. Following the demonstration, you will receive your copy of COINS.

COINS Software Request Form

Name: _____.

Company: _____.

Address: _____.

Phone: () - _____.

When is the best time to reach you by phone ? _____.

When is the best time to meet with you ? _____.

What type of computer do you own ? PC XT AT 386

What type of disk drive(s) does your computer have ? 5 $\frac{1}{2}$ 3 $\frac{1}{2}$

COINS

Citrus Cost Information System

Thank you for agreeing to evaluate the COINS program. We hope that you will benefit from the use of this program. Please take the time to read the **Quick Reference Guide** for general information and installation procedures.

COINS is still under development. It has been made available to you as part of a test which will help us improve the program to better fit your needs. We ask that you take some time to familiarize yourself with the program, and to use as many of its features as possible. An evaluation form is included with your package. **Please take the time to fill it out, and return it to us as soon as possible.**

COINS is based on a database of grove cost information. The program currently holds information on 50 groves growing several varieties of citrus in the Ridge area of Florida gathered in 1988. We are hoping the database will grow to include many more groves. Please use the Data Entry program to enter production costs for your operation. **Remember:** Your cost information will remain in the strictest confidence. We will not add your data to the database without your authorization.

Thank you again for using COINS and for participating in this evaluation. If you have any problems or questions please contact Ramzi Khuri at (904) 392-5979 or (904) 392-1864 and leave a message. For further information please write to:

Ramzi Khuri
Agricultural Engineering Department
Frazier Rogers Hall
University of Florida
Gainesville, FL 32611

COINS

Citrus Cost Information System

**Quick Reference Guide
1990**

General Information

A Citrus Cost Information System (COINS) was developed to collect, manage, and report costs associated with citrus production in Florida. The program consists of three main sections. The first is a data gathering program for production costs for various areas of the operation. The second section is a summary and reporting program which provides detailed summaries of averaged production costs, and allows a comparison to be made between production costs for a single grove, and industry averages. The third part is a decision support system that allows you to link extension and management recommendations with the appropriate production costs. Currently, a herbicide and weed guide is available to make management recommendations and provide information on related production costs.

How to Install COINS

COINS comes with its own install program. The program will be installed on your hard drive in a directory called C:\COINS. To run the install program, simply place the COINS INSTALL disk in your floppy drive and type INSTALL <source drive> <destination drive> (ex. INSTALL A: C:), then press return. To run the COINS program, go to the COINS directory on your hard drive, type COINS and press return.

Special Note: When using COINS, please make sure you exit the program through the menus. Do Not turn the computer off before properly exiting the COINS program. This will ensure that no information will be lost from the files.

The Data Entry Program

The following section describes the procedure for starting and using the data entry program to input or edit costs for a grove. Two options are available when the program is started. You may either define and enter costs for a new grove, or view and edit information for an existing grove.

From the main menu, select the Enter/Edit Costs option. You will then be asked for a password. Enter your password and press return. If this is the first time you use the system, enter NEW and press return. The program will ask you for a password. Enter a password of 20 characters or less in length. Write down your password and remember it. Your password is your key to using the system.

If you are not a new user, the program will ask you if you want to enter costs for a new grove, or modify information for an existing grove. Select one of the two options.

- **Defining a New Grove.** To enter costs for a new grove, you must define the characteristics of the grove. These include size in acres, fruit varieties, fruit market, yield in boxes of fruit, grove location, and grove ID number. A grove definition screen is used to enter the necessary data. A list of options is available from which you can select fruit varieties and grove locations. Once you have entered the required information, you must provide an ID number to identify the grove. This number is unique to your password. No one else will have access to this information.

The program will now display a spreadsheet of production costs categories. You are now ready to enter your grove costs. Use the arrow keys to move the blue highlight bar up and down to select categories, and right and left to select program functions. Please refer to the Program Functions section below for details.

- **Editing an Existing Grove.** If you choose to view or edit information for an existing grove, the program displays a menu of ID numbers corresponding to groves for which you had previously entered costs. By moving the menu selection bar to each ID number, the characteristics of each grove are displayed. Press return to select a grove. The program will display the cost information for that grove, and will allow you to view and modify the data. Please refer to the Program Functions section below for details.

- **Program Functions**

Edit. Data is entered using the edit function. When edit is selected, the production category on the highlight bar is highlighted in red, and a help window appears at the bottom of the screen. Costs for labor, machinery, management, and materials may be entered for each category. When editing is

completed, values in the separate cost columns are summed, and the results are placed in the overall cost column. The automatic summation may be suppressed by entering a value for the overall cost, or by using the mode function explained below.

Help. The data entry program features an on line help utility. When the help function is selected, an options window appears and allows you to select among several help topics. Help topics include an introduction to the purpose and uses of the program, a short tutorial, an overview of the database structure, an explanation of the ID number to identify groves, and lastly a help utility that explains each program function. The user may also obtain help on functions by moving the menu bar to the desired function, and pressing the F1 key.

Mode and Update. The mode function allows switching between auto-calculate and manual modes for column summation. When the program starts up, auto-calculate is on, and whenever separate costs for labor, machinery, management, or materials are entered, the program automatically adds these costs, and places the total in the overall column. The user may select manual recalculation in order to enter separate costs for the labor, machinery, management, and materials, as well as a separate overall cost. This feature is important when the user reports partial costs for a category, and the overall cost does not equal the total of the separate costs.

The update function is used to total the costs in the separate columns when mode is set to manual. The user may wish to total all costs, or just those in the current cost category.

Expand and Return. Each of the ten main cost categories is divided into one or more levels of sub-categories. The expand function is used to access the sub-categories for more detailed data entry. The return function allows the user to exit from a sub-category screen and return to a higher level in the hierarchy. A white triangle will appear to the left of a sub-category to indicate that further sub-categories are available.

Locate. The locate function serves two purposes. The first is to show a list of sub-categories available for a particular cost category. The second usage of the locate function is an index for all grove practices available in the database. This function is used to locate the main category under which a particular grove practice is found. For example, to find the main cost category for 'Herbicide Application', the user searches through the index for the word herbicide. The index will indicate the main category as being 'Cultivation'.

Comment and Product. The comment function allows you to enter a comment for each cost category. Comments may be used as notes or reminders. Similarly, the product feature allows you to enter a description of the product name, or material

being used in a particular grove practice. weeds, chemicals, or other products used in the citrus operation.

Back. Use the back function to return to the main menu. All changes you have made or information you have entered will be saved.

- **To Delete a Grove from the Database:** Select Enter/Edit Costs from the main menu. Then select the Delete a Grove option. Enter a grove ID number to delete and press return. When the grove is deleted, press any key to return to the main menu.

Data Summary and Reporting Program

The data summary and comparison program provides industry averages for citrus production costs. It also provides a means for comparing your grove costs to the industry averages.

The summary screen provides average per acre costs and returns for the ten main cost categories, as well as both levels of subcategories. A separate column for the range of costs is also provided. Per acre average labor, machinery, management, and material costs are also displayed. The following section describes the procedure for starting and using the data summary program to average, view, and compare costs.

• Cost Averaging.

From the main menu, select the **Data Summary** option. You will be asked for a password. Enter your password and press return. If you have not yet entered any grove costs using the data entry program, enter **NEW** and press return.

The program will now display a grove description screen. You are required to specify parameters which determine the types of groves that will be used in the summary. Maximum and minimum grove sizes, fruit types, fruit market (fresh or process), as well as location of the groves must be specified. You may be either very general whereby only one or a few parameters are specified, or very specific.

The program also allows you to specify one of your groves to compare to the averages. If a grove is specified, per acre costs for that grove will be displayed alongside the averages in the summary screen. **NOTE:** If you have not yet entered grove costs using the data entry program, you will not be able to make a comparison.

Once all the necessary information has been entered, the program will begin to average the information found. This may take a few minutes depending on how many groves were found that fit your description. **Please Be Patient.** If you wish to exit this program at any time press **F10**.

Once the summary screen is displayed, you may choose to explore the different average values in the different subcategory levels as well as view the individual labor, machinery, management, and material per acre costs. If you have chosen to compare the averages to costs from one of your groves, your per acre grove costs will be displayed on the column to the far right of the screen. Small yellow arrows to the right of a cost indicate categories showing higher cost than the average.

• Program Functions

For the purpose of avoiding repetition, only those functions that differ from the data entry program menu will be discussed. Please refer to the program functions under the **Data Entry** section above for more details.

Options. The options function is not active at this time. Additional features will be added to the program in the future.

Labor, Machinery, Management, Material. These options are used to display separate per acre overall costs and returns.

Herbicide and Weed Guide

The herbicide and weed guide provides herbicide recommendations and related cost information. It also provides a way to compare the effectiveness of several herbicides on a weed problem. A listing of weeds controlled by each herbicide is also available.

The program is fairly simple to use and requires you only to follow the instructions on the screen. In most cases, there is an instruction window at the bottom of the screen. The **ESCAPE** key will almost always return you to a previous screen, and the **F10** key will abort the program.

The Herbicide and Weed Guide has several features. The following is a brief description and instruction for each feature.

- **To get a list of weeds controlled by a particular herbicide:**
1) Select the Herbicide option from the main menu. 2) Move the cursor bar to the desired herbicide and press return. 3) Select a weed category. 4) Use the cursor bar to browse the list of weeds. 5) Press return to access the recommendations program. 6) You will need to answer a few questions to get recommendation and cost information on control of this weed.
- **To compare the effectiveness of several herbicides on weeds:**
1) Select the Herbicide option from the main menu. 2) Move the cursor bar to each herbicide desired and press the space bar to select. 3) Press return when done selecting herbicides. 4) Select a weed category or combination of categories. 5) Select weeds in each category. 6) A summary screen for each herbicide will be displayed. 7) Use the up and down arrow keys to select herbicides. 8) Press return to access the recommendations program. 9) You will need to answer a few questions to get recommendations and cost information for each herbicide.
- **To get a herbicide recommendation:**
1) Select the Weed option from the main menu. 2) Select a weed category or combination of categories. 3) Select weeds in each category. 4) If one herbicide is recommended, press return to get recommendations and cost information. 5) If more than one herbicide is recommended, select the desired herbicide and press return to access the recommendations program. 6) You will need to answer a few questions to get recommendations and cost information. 7) If no herbicides are found to control all weeds selected, you may choose the best herbicide for all weeds selected, or the best herbicide for weeds selected in each category. Once the desired herbicide is found, press return to get recommendations and cost information.

EVALUATION**COINS - Citrus Cost Information System**

We would like to have your comments concerning COINS. This will help use to improve the program. We appreciate your help and ideas on making COINS a more useful information tool. In responding to the questions, please make comments and suggestions where appropriate.

1. Please indicate the extent to which you feel you will use the following components. (1=frequently; 2=sometimes; 3=rarely; 4=never use)

Data entry program
 Summary and comparison
 Herbicide and weed guide

2. Using the scale provided, please rate COINS for the following general aspects. (1=excellent; 2=good; 3=fair; 4=poor)

Ease of installation
 Directions for use
 Overall speed of accessing information
 General ease of use of programs
 Quality and usefulness of help utility

3. Please rate the Data Entry Program for the characteristics listed. (1=excellent; 2=good; 3=fair; 4=poor)

Thoroughness of grove definition parameters
 Usefulness as a data entry and storage tool
 Thoroughness of cost categories
 Usefulness of sub-categories
 Thoroughness of sub-categories
 Usefulness of menu functions
 General ease of use of program

4. Please rate the Summary and Comparison Program for the characteristics listed. (1=excellent; 2=good; 3=fair; 4=poor)

Thoroughness of search parameters
 Usefulness as an information tool
 Usefulness as a cost comparison tool
 Usefulness as a decision making tool
 Usefulness of information to your operation
 Usefulness of menu functions
 General ease of use of program

5. Please rate the **Herbicide and Weed Guide** for the characteristics listed. (1=excellent; 2=good; 3=fair; 4=poor)

- Thoroughness of list of herbicides
- Thoroughness of list of weeds
- Usefulness of herbicide recommendations
- Usefulness of comparing several herbicides
- Usefulness in showing weeds controlled by a herbicide
- Usefulness of cost information on herbicides
- Usefulness of printed reports
- Usefulness as a decision making tool
- Usefulness of information to your operation
- General ease of use of program

6. Will you be willing to share your own cost information with other growers provided the confidentiality of your name and operation are assured? YES NO

7. In summary what do you see as the strong points of COINS.

8. How can COINS be made more useful to you?

9. Please provide us with the following information:

Name: _____
Company: _____
Position (grower, manager, etc.): _____
Size of operation: _____
Type of operation: _____
County in which groves are located: _____

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BIOGRAPHICAL SKETCH

Ramzi Khuri was born May 9, 1964, in Beirut, Lebanon. In June 1982, he graduated from the International College in Beirut. He received his Bachelor of Science degree in agriculture from the American University of Beirut, Lebanon, in June 1985.

In August 1985, Ramzi enrolled as a graduate student in the Agricultural Engineering Department at the University of Florida. He was employed as a graduate research assistant for Dr. W. D. Shoup. His duties involved working with Florida citrus growers to improve citrus harvest management techniques. He graduated in August, 1987 with a Master of Science degree (agricultural operations management).

He was accepted as a Ph.D. student in agricultural engineering at the University of Florida in 1987. Ramzi was again employed as a graduate research assistant, this time for Dr. Howard Beck. His research responsibilities included the design and development of a citrus production cost information system.

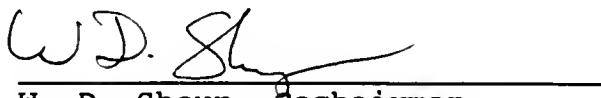
Ramzi has accepted a job at EXXON U.S.A. in Houston, Texas, as an Associate Staff Systems Analyst in the Information and Communication Systems department. His responsibilities will include work with information systems,

database management systems, expert systems, and end-user support.

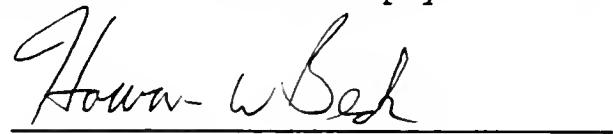
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R. M. Peart, Chairman
Graduate Research Professor of
Agricultural Engineering

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Professor of Food and Resource
Economics

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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